Entry Deterrence in Procurement Auctions*

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Abstract

Firms have incentives to alter competitors' beliefs about their entry to deter others from entering the market. They may achieve this objective by disclosing their intent to enter. We study procurement auctions conducted by Montana Department of Transportation, where a designated online Q&A forum serves as an entry disclosure device. We specify and estimate a model of procurement auctions with costly entry, in which firms have the option to disclose entry. We find that disclosure deters entry from others, and disclosure is beneficial for a firm if they can disclose at an early period. Overall, the availability of disclosure device decreases the auctioneer's payment by 6.3%, while increasing the winner's construction costs by 4.5% and decreasing the total entry costs by 11.1%.

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1 Introduction

When multiple firms contemplate entering a market, there may not be sufficient capacity for the market to profitably accommodate all potential entrants. Even if every firm prefers to be an entrant ex-ante, some firms ultimately enter while others stay out. In such an environment, belief about others' entry is crucial. As discussed in Farrell (1987), if a firm can influence the beliefs of other firms regarding its intent to enter, it may compel those other firms to reconsider their own entry decisions. For instance, once all potential entrants believe that a given firm will enter the market, this can benefit the firm since the other firms may then be less inclined to enter.

In attempting to influence the beliefs of rival firms and deter their entry, it is common for firms to publicly announce one's intent to enter the market. For example, a firm may make a pre-announcement on releasing new products for this purpose. In the early 1990s, Microsoft was accused of making product pre-announcements just for the purpose of deterring competitors from entering. The district court judge noted that "Microsoft could unfairly hold onto this [dominant] position with aggressive pre-announcements of new products in the face of the introduction of possibly superior competitive products." [1] Although strategic entry deterrence through disclosure raises concerns from an antitrust perspective, there is a notable lack of empirical research quantifying this effect.

In this paper, we investigate how entry disclosure affects auction outcomes by studying procurement auctions conducted by the Montana Department of Transportation (MDOT). A notable feature of the auctions that we study is that there is a designated online forum on MDOT's website, where potential bidders can post questions about the project being let. The questions, the identity of the firm asking, the posting time, as well as MDOT's responses, are all publicly accessible information. The most important feature is that the forum gets continuously updated: questions become publicly visible almost immediately after posting. Since posting a question on the forum typically requires a firm to have invested some time in reviewing the project plan, posting a question on the online forum serves as an entry disclosure. Indeed, over 99% of the questions are posted by actual entrants. By linking the activity on the forum to entry

[1] The ruling of Judge Stanley Sporkin in Civil Action No. 94-1564 (United States of America v.s. Microsoft Corporation 1995).

and bidding behavior in the auction, we study the effect of entry disclosure on auction outcomes, such as equilibrium entry, government payments, and efficiency in terms of the winner's cost.

To understand how participating firms perceive the Q&A forum, we conducted interviews with the participating firms. Their responses reveal that the firms indeed perceive that questions are posted in a strategic manner and not always intended to gather information about the project:

> "*There is always a strategical consideration to the questions we ask and is not solely determined by us needing the information. It can be gamesmanship with the other bidders.*"

Moreover, their claim indicates that they take the questions as a *credible* signal for a firm entering the auction:

> "*It's safe to assume that contractors would not be asking questions unless they are going to bid the project.*"

These claims support the idea of considering the Q&A forum as a disclosure device, which forms the foundation of the paper.

In our setup, entry disclosure has two distinct and competing effects. First, as noted earlier, a firm can alter opponents' beliefs through disclosure, thereby reducing their expected profits from entry, which consequently leads to less entry from other firms. On the other hand, a key feature of our setup is that the set of entrants remains unknown at the time of bidding, while the firms that have disclosed entry will be participating in bidding for certain. This uncertainty regarding the set of entrants generates a countervailing force to entry deterrence. Knowing that a firm would certainly be bidding due to disclosure, the other firms that do enter may bid more aggressively against the firm, compared to the case where the firm remains silent about their entry status. Thus, entry disclosure through posting questions can ultimately disadvantage the firms who have disclosed entry.

To understand the trade-off between the two competing effects of entry disclosure, we construct and estimate a model of a procurement auction with costly entry, wherein firms can post questions on a Q&A forum that serves as an entry disclosure device.

Our model consists of two stages: (i) entry and disclosure; and (ii) bidding. In the first stage, firms sequentially arrive at the market. They make entry decisions based on their private entry costs and information available on the Q&A forum – specifically, the firms are aware of who has disclosed entry. Upon entry, firms draw their construction costs and may choose to post a question on the forum, thereby disclosing its entry.

The second stage occurs after all the entry decisions have been finalized. Entrants submit their bids simultaneously, taking into account all disclosures and their own private construction costs. The bidding procedure is a first-price sealed bid auction, and the bidder with the lowest bid wins. The effect of introduction of the Q&A forum on auction outcomes is ambiguous and thus an empirical question. From a policy perspective, a recent survey highlights that DOTs vary in their treatment of entry information, where 40% of them provide the identity of the firms who enter before the bidding happens, while others do not (Liscow et al. 2024). Using the estimates, we consider how the auction outcomes change by alternative platform designs regarding transmission of information about entry.

We establish three key patterns that illustrate the economic forces of the posted questions, i.e., entry disclosure. First, we document that the presence of a question on the forum is associated with a lower entry probability among bidders. This is a pattern we would see if disclosures indeed deter entry. Second, the strongest bid from opponents is weaker for the firms who disclose early compared to: (i) those who never disclose; or (ii) those who disclose late. If early entry disclosures have a strong effect of entry deterrence, dominating its effect on inviting in more aggressive bids, we would observe this pattern (i). In addition, we expect pattern (ii) to hold, as late disclosures are expected to have weaker effects of entry deterrence than early disclosures in a sequential entry setting. Third, entrants submit stronger bids when faced with a greater number of questions. This pattern aligns with the expectation that firms' bidding behavior responds to the information presented on the Q&A forum.

We also document patterns that do *not* align with alternative forces that could be in play. One such alternative force that could explain the first pattern presented above is variation in quality of the proposals across auctions. If the presence of a question serves as a proxy for proposal quality, we would expect to see a similar pattern, where this proxy is associated with a lower entry probability among bidders. However, we observe that bids are stronger in auctions where questions are present. This pattern contradicts the alternative explanation, since we would expect weaker bids if the proposal has low quality. Therefore, we believe that this factor is unlikely to be the primary driver of our data.

We show that the primitives of the model are non-parametrically identified from firms' entry, disclosure, and bidding behaviors. The primitives we aim to recover are the distribution of firms' arrival timing, entry costs, costs associated with entry disclosure, i.e., posting questions, and construction costs. The primary challenge in identification arises from the fact that entry timing is only observed for the firms who disclose their entry. In the first step, we recover the construction costs and their distribution, following the methodology from Guerre et al. (2000). Next, we recover a firm X's belief on the evolution of disclosure history, conditional on X entering at a fixed time point. If firm X discloses their entry, this object is directly identified from the observed patterns. However, if X does not disclose, we cannot identify firm X's belief directly from the data, since we do not observe their entry timing. To overcome this problem, we construct a mapping from the observed pattern of disclosures to a firm's belief on the evolution of disclosure histories. The idea is to treat the setup as a survival analysis with competing risks. Here, the event is an entry disclosure, and the possibility of multiple firms disclosing can be seen as competing risks. Our conditional independence assumption between the firms allows us to identify each firm's duration until they make a disclosure, starting from any time point (Tsiatis 1975). We can now construct a firm X's belief on evolution of disclosure history, since each firm's duration until disclosure is known under any history.

The remaining primitives – specifically, distribution of firms' arrival timing, entry costs, and costs of entry disclosure – are identified through the following five steps. First, by considering the expected value from the auction stage and the belief on the evolution of disclosure history, we are able to determine the value function with/without disclosure and thus value of disclosure, at each history and construction cost. Second, by exploiting variation in the amount of disclosures and values of disclosure at the same history but under different construction costs, we can identify the distribution of disclosure costs. Third, given the knowledge of values with/without disclosures, along with the distribution of disclosure costs, value of entry is identified for each disclosure history. Fourth, by exploiting variation in the amount of disclosures, value of entry, and value of disclosure at the same time under different disclosure histories, we can identify the distribution of entry costs. Finally, we can identify the distribution of entry timing by comparing the amount of disclosures across different time points.

Given our estimates, we can quantify the value of disclosure. First, we show that disclosure is beneficial for firms at the beginning of the entry period, but becomes detrimental toward the end. For a bidder with median construction costs, the value of disclosure is 1.5% of the estimated project cost at the beginning, whereas it becomes costly by the end. The intuition behind this finding is that if a bidder enters early and discloses, they can deter entry from others, even though remaining entrants may bid more aggressively. In our scenario, the deterrence effect dominates. However, if a bidder enters late and discloses, the force of entry deterrence diminishes since there are fewer potential entrants remaining on the sideline. As a result, aggressive bidding from other entrants negatively impacts the late-disclosing bidder. Next, stronger bidders who have smaller construction costs derive larger values from disclosure. At the beginning of the entry period, the value of disclosure is 2.1% of the engineer's estimate for a bidder whose cost is at the 25-th percentile, while the value is 0.7% for a bidder at the 75-th percentile. This result indicates that entry disclosure also serves as a signal of a bidder's strength.

We also quantify the value of entry, and show how it changes by the presence of disclosures. First, we find that the value of entry increases as we progress to later periods, holding the number of disclosures available at the firms' arrival time fixed. Under the case where there are no disclosures, value of entry is 9.8% of the engineer's estimate at the beginning of the entry period and rises to 10.5% by the end. At a fixed time point, an increase in the number of disclosures decreases firm's value of entry, resulting in a reduction of their entry probability by 4–6%. These findings indicate that both arrival timing and the disclosures firms face have a significant impact on entry decisions. Finally, we show that the expected profit from arriving at the end is 7% lower than the the case when a firm arrives at the beginning. Early arrivals allows firms to capture greater gains from disclosures. Conversely, firms arriving late can make more efficient entry decisions due to increased information availability. In our setup, the former effect dominates.

In our counterfactual analysis, we compare equilibrium auction outcomes under three alternative scenarios: shutdown of the forum, where the Q&A forum is never made public; last minute disclosure, where the forum becomes public after the entry period but before the bidding occurs; and the status quo, where the current Q&A forum is available. We use the first scenario, in which the forum is shut down as our benchmark for exposition. Our objective is to understand the effects of entry disclosure, which operate through two channels: entry deterrence and provision of additional information at the bidding stage.

First, we make the Q&A forum public after the entry period ends. In this scenario, entry disclosures affect outcomes solely through the second channel – providing additional information when firms bid. Firms cannot deter entry, as the information only becomes public after firms have made their entry decisions. In this case, we observe a 0.8% increase in auctioneer's payment, a 1.4% increase in winner's construction cost, and a 3.2% increase in total entry costs. Firms still make disclosures, but only due to exogenous reasons, which forces them to reveal some of their private information, their entry status. McAfee & McMillan (1987) and Harstad et al. (1990) have pointed out that uncertainty about firm's entry does not affect the auctioneer's payment, when bidders are risk-neutral. In line with this result, we only see a small change in the auctioneer's payment. This small change comes from asymmetry among the bidders, which also creates efficiency loss in the winner's cost. Consider the following example: there are two entrants, firms X and Y. Firm X discloses its entry, while firm Y remains silent. Firm Y will adopt a more aggressive bidding strategy than firm X since they are sure about facing a competitor. Consequently, firm Y may win some auctions even when firm Y has a larger construction cost than firm X. This inefficiency does not arise when firms are symmetric and employ monotone symmetric strategies. The asymmetry created by different disclosure actions leads to inefficiency. Moreover, this asymmetry increases auctioneer's payment. Although the decrease in auctioneer's payment decreases and increase in the winner's cost mostly cancels out, total entry increases in equilibrium.

Next, we implement the current Q&A forum, allowing firms to deter others' entry by disclosing their intent to enter. In this case, We observe a more significant impact: relative to the benchmark, there is a 6.3% decrease in auctioneer's payment, a 4.5% increase in winner's construction cost, and an 11.1% decrease in total entry cost. The availability of the forum allows the firms to coordinate on their entry to some extent.

Coordination among the firms reduces the number of auctions where there is no competition, i.e., only one entrant. Since the possibility of a firm becoming the only bidder is the main force that increases the auctioneer's payment, coordination among the firms helps the auctioneer by reducing their payment. Another key observation here is that the stronger bidders with small construction costs are more likely to disclose their entry. As a result, disclosures serve as a signal for strength. While firms can deter entry through disclosure, they forfeit information rents associated with their entry status and strength. As a result, we see a decrease in auctioneer's payment. Moreover, this creates a "stronger" asymmetry among the entrants: firms who disclose will be bidding for certain and strong, while firms who stay silent may not be present and weak even if they do enter. Consequently, winner's cost increases.

In summary, the current platform introduces a new dimension regarding firms' types: arrival time. When a firm arrives early, to take advantage of this new dimension, they disclose their entry status to deter other firms' entry even at the cost of sacrificing information rents. Consequently, this leads to a decrease in auctioneer's payment. Furthermore, disclosures put firms into asymmetric positions, resulting in inefficiency in terms of the winner's cost. Together, we find that the existence of the Q&A forum, which allows the firms to send out some information, has a significant impact on auction outcomes. More broadly, these results suggest that market designers must exercise caution in how information is transmitted before agents take actions.

Related Literature The paper contributes to two strands of literature—the literature on strategic entry deterrence and the literature on costly entry into auctions.

The paper provides an empirical equilibrium analysis to test how strategic entry deterrence can affect market outcomes, taking entry disclosure as a tool to deter entry. A significant amount of theoretical work on strategic entry deterrence has been carried out, e.g., Dixit (1979), Milgrom & Roberts (1982), and Farrell (1987). However, empirical work on this question is still limited. Goolsbee & Syverson (2008) and Sweeting et al. (2020) study how limit pricing by the incumbent affects entry behavior in the airline market. Scott Morton (2000) and Ellison & Ellison (2011) studies strategic investment, such as advertisement, to deter entry in the pharmaceutical market. Ely & Hossain (2009) studies the effects of early period bidding in online auctions. Although they find a similar result to our paper that early period bidding deters entry but causes more aggressive bidding from the entrants, there are two important distinctions. First, Ely & Hossain (2009) tests for such effect by experimentally placing bids, while our analysis analyzes the effect of entry disclosure, which arises as an equilibrium behavior. Next, they study a second-price auction setup, while ours is a first-price auction. In second-price auctions, more aggressive bidding due to entry disclosure is not a pattern we would expect under a private-value framework, since bidding their own value would be an undominated strategy for the bidders. In contrast, entry disclosure may cause more aggressive bidding from others under our setup, sealed-bid first-price auctions with private values.

The paper also relates to the literature on costly entry into auctions. Overall, the literature has pointed out the importance of incorporating entry costs in analysis of auctions. Ye (2007) and Quint & Hendricks (2018) theoretically studies indicative bidding; De Silva et al. (2008) studies the effect of releasing information about seller's valuation on bidding in procurement auctions; Krasnokutskaya & Seim (2011) studies how the introduction of bid preference program affects firms entry and bid decisions; and Gentry & Li (2014) studies non-parametric identification of an auction game with selective entry. The paper also studies a setting where entry is costly, but is the first to study how entry disclosure can deter entry from others in first-price auctions with costly entry.

2 Institutional Background and Data

2.1 Institutional Background

We describe the letting process of procurement auctions conducted by the Montana Department of Transporation (MDOT). MDOT uses sealed-bid first price auctions to award construction projects. The set of firms who participate in bidding will not get disclosed by MDOT until the final auction result is announced.

MDOT advertises projects four weeks prior to the bidding date, providing detailed specifications of each project. On the same day as the advertisement, a Q&A forum is launched on MDOT's website. On this forum, firms can post questions about the project, and MDOT provides answers to the posted questions. The questions become publicly visible when the firms post them, subject to a quick review by the MDOT. Answers from MDOT are provided within two days in most cases. The forum displays

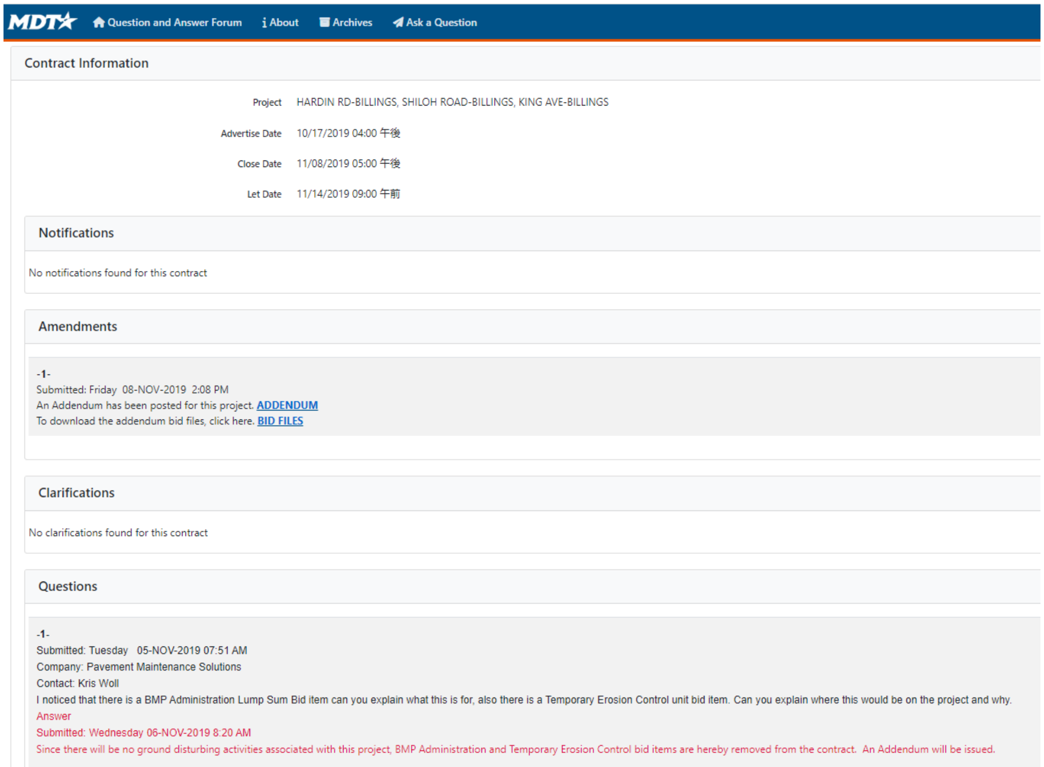

Figure 1: Screenshot of the Q&A forum

the time at which the question got posted, the name of the company, the contact person, the question, and the corresponding answer. Figure 1 presents a screenshot of the forum. The forum remains active until three days before the bidding window closes. While other public procurement auctions also accept questions from the firms, the unique feature here is that this forum gets continuously updated along with identity of the firms who posted questions and a timestamp.

The questions posted on the forum vary in value. Some turn out to be valuable, while others offer little additional information. For example, a question pointed out that there is an unnecessary item listed in the contract. MDOT responded by removing the item from the contract and issued an addendum.[2] On the other hand, MDOT responds to some questions by referring firms to existing documents, instructing them to review the relevant sections.[3] This observation is in line with the quote from a firm presented above that some questions are not solely intended to obtain information.

[2]For example, see https://app.mdt.mt.gov/qaf/external/archive/view/493

[3]For example, see question #1 from https://app.mdt.mt.gov/qaf/external/archive/view/463

Table 1: Summary Statistics

	Mean	Standard deviation	10th percentile	Median	90th percentile
Engineer's estimate ($000)	2,949	4,315	144	1,297	8,597
Lowest bid ($000)	3,022	4,702	154	1,225	8,382
Lowest bid / Engineer's estimate	1.021	0.314	0.750	0.965	1.320
#Entrants	2.82	1.50	1	3	5
#Potential entrants	12.44	5.62	4	12	20
#Questions	0.83	0.97	0	1	2
Type of projects	N	percent			
Bridge construction	51	11.8			
Overlay	78	18.0			
Reconstruction	46	10.6			
Safety	67	15.4			
Others	192	44.2			
Districts	N	percent			
Missoula	94	21.7			
Butte	76	17.5			
Great Falls	113	26.0			
Glendive	73	16.8			
Billings	78	18.0			

Note: Total number of projects is 434. There were 5 auctions without an entrant.

To participate in bidding on a project, firms must prepare the necessary documents and submit them along with their bids. They must also engage in negotiations with subcontractors. These tasks involve significant costs, as they require substantial time and effort. As a result, entry into auctions is inherently costly.[4]

2.2 Data

Our data covers projects auctioned between January 2017 and December 2022. For each auction, it includes the project description, location, the engineer's estimate of the total cost of the project, and the submitted bids along with the identity of the bidding firms. Additionally, the dataset contains information from the Q&A forum, including the posted questions, MDOT's responses, identities of the firm who posted the questions, and the timestamps of the posts. During the sample period, 592 projects were advertised, while we focus on 434 projects whose construction reports were available, which allow us to identify the type of construction of the projects.

[4]Costliness of entry into procurement auctions have been pointed out in the literature (e.g., Li & Zheng (2009)).

Table 1 presents summary statistics of the auctions. The median engineer's estimate is approximately \$1.30 million, while the median winning bid is around \$1.22 million. For our analysis, we will normalize the bids by the engineer's estimate. The median normalized winning bid is 3.5% below the engineer's estimate. MDOT reserves the rights to reject all the bids, and 16 auctions during the sample period experienced such rejections.[5] On average, we have three entrants. We define potential entrants as firms that entered in at least one auction within the same district × type of construction pair during the sample period. A typical auction has 12 potential entrants. Regarding the Q&A forum, we observe slightly fewer than one question per auction on average.[6] There is some variety in the types of projects, with overlay projects being the most common (18%).[7] Project distribution is relatively balanced across districts, although the Great Falls district accounts for the largest share (26%).[8]

3 Model

In this section, we develop a model of a procurement auction with costly entry and the option for firms to disclose their entry. The auctioneer seeks to procure a project through a first-price auction. There are N potential bidders who may choose to participate in bidding. We denote the set of potential bidders as $\mathcal{N} = \{1, \cdots, N\}$. In our empirical application, the questions submitted to the Q&A forum serve as entry disclosures.

The model consists of two stages: (i) entry and disclosure; and (ii) bidding. In the first stage, firms sequentially arrive at the market randomly without knowledge of others' arrival times. When they arrive at the market, firms observe the disclosures that have been made, make decisions on entry, and choose whether to disclose if they enter. Once the first stage concludes, the entrants proceed to the second stage, which involves bidding. In this stage, firms observe the complete history of disclosures, and

[5] If bids are rejected, the project may be revised and advertised at a later date.

[6] We only include the questions submitted by the potential entrants. Moreover, there are some cases where a firm posts multiple questions. We only keep the first questions from such firm in our dataset.

[7] We follow the categorization of types of construction provided in the construction reports provided by MDOT. Some projects fall under multiple categories and if so we assign the project to the more popular type.

[8] We split the state into five districts, following the coverage of five MDOT district offices. See https://www.mdt.mt.gov/contact/organization/districts.aspx

place bids simultaneously.

First stage An auction is announced and the Q&A forum, serving as the disclosure device, becomes available at $t = 0$. The disclosure device closes at $t = T$, although disclosures will remain observable after its closure. Each potential bidder $i \in \mathcal{N}$ draws $\tau_i \in [0, T]$ from the distribution F_τ, which represents the time at which bidder i decides whether to participate in the auction. At $t = \tau_i$, firm i arrives at the market, observes the disclosure history h^{τ_i}, and draw its entry cost c_i^E from distribution F_E. The disclosure history h^t is public information and records the time at which questions are posted as well as the the identities of the posting firms, up to time t. We denote the set of all time-t histories as $\mathscr{H}^t$. The entry cost, c_i^E encompasses the cost of reviewing the project plan, assessing required materials and labor, negotiating with subcontractors, and arriving at a cost estimate. Firm i may choose to enter the auction by paying the entry cost c_i^E or opt to remain out without incurring any costs. We denote the firm i's entry strategy as: $\chi_{i,\tau}$: $\chi_{i,\tau}(h^\tau, c_i^E) \mapsto a_i^E \in \{0, 1\}$.

If firm i decides to enter the auction, at the same time $t = \tau_i$, it draws its construction cost c_i, and faces an opportunity to disclose its entry. With probability p^Q, firm i faces a need to disclose and always discloses without paying any additional cost. During the review of the project plan, issues may arise that prevent the firms from making progress in the process. This part reflects such scenario and assume that it happens with probability p^Q. With the other probability $1 - p^Q$, firm i may opt for costly disclosures by paying a disclosure cost c_i^Q, which follows the distribution F_Q. This cost can be viewed as the expense associated with formulating an appropriate question, as well as a potential reputation cost. Only firms that have entered the auction are allowed to make disclosures. We denote firm i's disclosure strategy as: $\iota_{i,\tau}(h^\tau, c_i, c_i^Q) \mapsto a_i^Q \in \{0, 1\}$. If firm i discloses, disclosure history h^τ is updated accordingly.

Second stage After the forum closes at $t = T$, entrants – the firms who have entered – participate in bidding. The auction format is a sealed-bid first price auction. Before placing their bids, the entrants observe the complete disclosure history h^T. Given h^T, the entrants submit their bids b_i simultaneously. We denote the firm i's bidding strategy as: $b_i(h^T, c_i) \mapsto \mathbb{R}$. The payoff π_i for firm i is given by:

$$\pi_i = (b_i - c_i)\mathbb{1}\{i \text{ wins}\} - c_i^E a_i^E - c_i^Q a_i^Q,$$

where the first term represents gains from the auction, the second accounts for the entry cost, and the third is the disclosure cost.

Assumption on firms' types As described above, each firm i's type is characterized by the tuple $(\tau_i, c_i^E, c_i^Q, c_i)$. We assume that these four random variables are mutually independent, with draws across firms being independent and identically distributed.

Equilibrium We consider the Perfect Bayesian Equilibrium of the game presented above. Equilibrium consists of firms' strategy profile $(\chi_{i,\tau}, \iota_{i,\tau}, b_i)$ such that:

1. firm i enters ($a_i^E = 1$) if and only if its expected profit from entry exceeds the entry cost c_i^E:
$$\mathbb{E}\left[\pi_i | h^{\tau_i}, a_i^E = 1\right] > c_i^E$$

2. firm i costly discloses ($a_i^Q = 1$) if and only if its expected gain from entry exceeds the disclosure cost c_i^Q
$$\mathbb{E}\left[\pi_i | h^{\tau_i}, a_i^E = 1, a_i^Q = 1\right] - \mathbb{E}\left[\pi_i | h^{\tau_i}, a_i^E = 1, a_i^Q = 0\right] > c_i^Q$$

3. firm i bids b_i that maximizes its expected profit conditional on the complete disclosure history h^T and construction cost c_i
$$b_i = \arg\max_b (b - c_i)\Pr(i \text{ wins} | h^T, b).$$

In addition, firms have consistent beliefs given the strategy profile. We assume that an equilibrium exists, and if there are multiple equilibria, we assume that one equilibrium is selected and played.

Discussion of the model In our setup, entry disclosures occur through the posting of questions .Consequently, firms may sometimes need to post questions to address issues that arise during their preparation for bidding, even if their primary motivation is not to disclose their entry. Our model does incorporate this feature. However, it does not account for informational spillovers that may benefit other firms. Our estimates indicate that the best bid from the opponents tend to be weaker when a firm discloses its entry, holding others' disclosure activities fixed. If information spillovers had first-order effects that outweighed the effects of entry disclosures, the sign of this effect would be the opposite. Therefore, we believe that this is not a primary concern in our model, though informational spillovers may exist.

3.1 Example: Two firms

Here, we provide a simple example with two firms. The purpose of this example is to illustrate the main economic forces that emerge from the option to disclose entry.

There are two firms i and j who are ex-ante symmetric. We assume that the distribution of arrival timings follow $F_\tau \sim U[0,1]$,[9] the distribution of construction costs follows $F_c \sim U[0,1]$, and disclosure can be made at no cost, i.e, $c_i^Q = c_j^Q = 0$. Moreover, firms are never forced to disclose their entry, $p^Q = 0$. We leave the distribution of entry costs F_E to be unspecified at this point. Suppose that there is a reserve price $R = 1$.

For some entry cost distribution F_E, there exists an equilibrium that consists of the following strategies:

1. Second stage: Bidding

    - If h^T includes two disclosures or none: bid $b_i(c_i) = (1 + c_i)/2$.

    - If h^T includes one disclosure and that is from i, firm i bids $\beta_1(c)$ such that

$$\beta_1^{-1}(b) = 1 - \frac{1}{(b - \frac{1}{r})\left(\frac{r^2}{(1-r)^2}\log\left(\frac{1-b}{\frac{1}{r}-b}\right) - \frac{r}{1-r}\frac{1}{b-\frac{1}{r}} - r(1+r) - \frac{2r^2}{(1-r)^2}\log(r) - \frac{r^2(1+r)}{1-r}\right)}$$

    where β_1^{-1} is the inverse bid function, and r is i's belief on j's entry proba-

[9]This assumption is made for simplicity. It can be any continuous distribution without a mass.

bility. Firm j bids $\beta_2(c)$ such that

$$\beta_2^{-1}(b) = \frac{1}{r} - \frac{1}{\frac{r}{1-r} + (b-1)\left(\frac{r^2}{(1-r)^2}\log\left(\frac{\frac{1}{r}-b}{1-b}\right) - (1+r) + \frac{2r^2}{(1-r)^2}\log(r) + \frac{1+r}{1-r}\right)}$$

where β_2^{-1} is the inverse bid function.

2. First stage: Entry

   - If h^τ does not include any disclosures, firms always enter $\chi_{i,\tau}(h^\tau, c_i^E) = 1$.
   - If h^τ includes one disclosure, firm enters $\chi_{i,\tau}(h^\tau, c_i^E) = 1$ if and only if $\pi_2 > c_i^E$, where π_2 is the expected profit from the bidding stage.

3. First stage: Disclosure

   - If h^τ does not include any disclosures, firms always disclose $\iota_{i,\tau}(h^\tau, c_i) = 1$.
   - If h^τ includes one disclosure, firms never disclose $\iota_{i,\tau}(h^\tau, c_i) = 0$,

and consistent beliefs, given these strategies. The construction for the bidding part follows Kaplan & Zamir (2012).

The required conditions for the entry cost distribution F_E are:

- firms always enter under no disclosure:

  $$F_E(\pi_1) = 1$$

  where π_1 is the expected profit from the bidding stage for the case where you have disclosed but your opponent has not.

- firms enter with probability r when there is one disclosure:

  $$F_E(\pi_2) = r$$

  where π_2 is the expected profit from the bidding stage for the case where your opponent has disclosed but you have not.

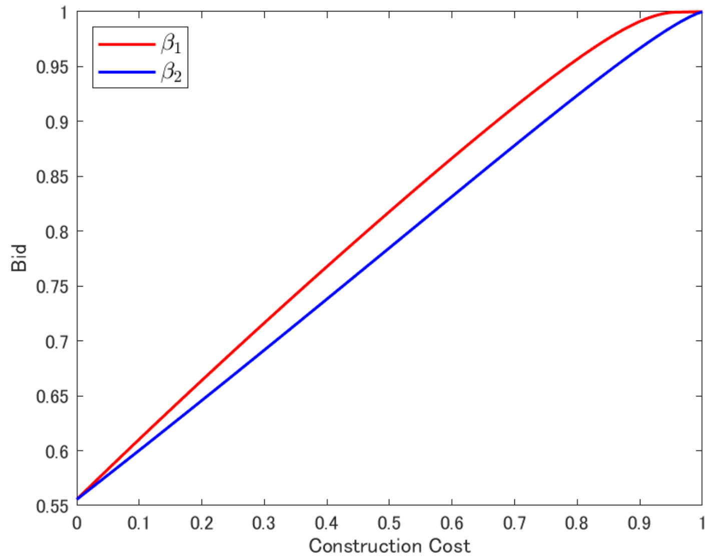

Figure 2: Example: Bid Function

Notes: This figure shows the bidding functions employed in our two firm example, for the case $r = 0.8$.

This equilibrium presents multiple key observations that may arise from an environment with entry disclosures. First, entry disclosure deters entry subsequent firms from entering the auction after a disclosure has been made. The firm that arrives first always discloses, which decreases the entry value for the next arriving firm, thereby reducing its probability of entry.

Second, early disclosures are valuable, while late disclosures are detrimental. We observe that only the firm who arrives first chooses to disclose, as disclosure is beneficial for that firm. In contrast, the firm that arrives second finds that disclosing only prompts the first firm to bid more aggressively, leading it to refrain from making a disclosure.

Third, entry disclosure compels the other firm to bid more aggressively. To illustrate this, we can compare the scenario in which the first firm discloses with the scenario in which it does not. In the former case, the second firm employs strategy β_2, while in the latter case, it employs strategy β_1. As shown in Figure 2, β_2 represents a more aggressive strategy.[10] Therefore, conditional on the other firm entering, the other firm bids more aggressively when faced with a disclosure.

[10]This claim holds for any entry probability of the second firm, r.

Here, through a simple example, we have shown three key observations that are expected to arise in an environment where entry disclosure is an available option. In the following section, we provide evidence that our data aligns with these key observations.

4 Preliminary Analysis

We use the data to establish three empirical facts that highlight the trade-offs firms face when considering disclosures: disclosure may deter entry from other firms, and it may also compel other entrants to bid more aggressively. First, we examine the relationship between the presence of a question on the forum and firms' entry probability. Second, we analyze how the timing of questions and bids from opponents are related. Finally, we show how bids are related to the number of questions that a firm encounters.

Fact 1: Presence of a question and entry probability

As we have seen in Section 3.1, entry disclosures may deter entry from others. If a question serves as an entry disclosure and deter entry from others, presence of a question on the forum would reduce the probability of entry from other firms. To assess the relationship between the presence of a question and entry probability, we run the following regression:

$$\mathbb{1}\{\text{firm enters}\}_{ia} = \beta_0 + \beta_1 \mathbb{1}\{\text{question is posted from an opponent}\}_{ia} + \beta^X X_a + \varepsilon_{ia} \quad (4.1)$$

where i denotes the firm and a denotes the auction. Auction-level characteristics X_a include the number of potential bidders, type of construction, and district where the project is located. Our primary interest is in the sign of β_1. The first column from table 2 presents the results from this regression. We observe that presence of a question from opponents is associated with a 3.4 percentage point decrease in entry probability, and this association is significant at the 5% level. However, concerns may arise regarding within-auction variation influencing this result. Specifically, firms that post questions always enter, which mechanically results in fewer questions being visible on the forum within an auction. To mitigate such concern, we restrict our sample to firms that do not post a question. The second column of table 2 shows the results for this restricted sample. We find that the result is mostly unchanged.

Table 2: Presence of question and entry probability

	Dependent variable: Entry			
	(1)	(2)	(3)	(4)
Sample	all	only not posted	all	only not posted
Q from opponent is present	-0.034	- 0.041		
	(0.014)	(0.012)		
Number of Qs from opponent				
1			-0.030	-0.039
			(0.017)	(0.013)
≥ 2			-0.042	-0.044
			(0.020)	(0.015)
Auction-level characteristics	Yes	Yes	Yes	Yes
N	5,397	5,042	5,397	5,042

Note: Results in columns (1) and (3) is based on the entire sample of potential entrants. Results in columns (2) and (4) is based on the sample of potential entrants who have not posted a question. Standard errors are clustered at the auction level.

We also investigate how this relationship varies with the number of questions firms observe on the forum. To do this, we run the following regression:

$$\begin{aligned}\mathbb{1}\{\text{firm enters}\}_{ia} &= \beta_0 + \beta_1 \mathbb{1}\{\text{One question is posted from an opponent}\}_{ia} \\ &\quad + \beta_2 \mathbb{1}\{\text{Two or more questions are posted from an opponent}\}_{ia} + \beta^X X_a + \varepsilon_{ia}.\end{aligned}$$

Our interest lies in the signs and the relative magnitudes of β_1 and β_2. We again observe a negative relation between presence of opponents' questions and entry probability. Although the strength of this relationship by the number of questions is not statistically different (β_1 and β_2), our point estimate for the coefficient on seeing two or more questions is larger than the coefficient on seeing one question.

Together, the relationship between presence of opponents' questions and firms' entry probability in our data aligns with the hypothesis that questions deter entry from others.

Fact 2: Timing of questions and bids from opponents

Suppose that questions serve as an entry disclosure. Disclosures made in early periods may have strong deterrent effects, while other entrants may bid more aggressively compared to the case where the firm had stayed silent. On the other hand, late disclosures may be detrimental because they may lack deterrent effects, while other entrants still bid aggressively.

Now, note that from one entrant's point of view, their profit depends on the best bid among their opponents in a first price auction. If the deterrent effect from early disclosures is strong enough, we would expect to observe weaker best bid from opponents compared to scenarios where the firm does not disclose or disclose late. To evaluate the relationship between timing of question postings and best bid from opponents, we run the regression:

$$\wedge \mathbf{b}_{-i,a} = \beta_0 + \beta_1 \mathbb{1}\{\text{posted a question}\}_{ia} + \beta_2 \mathbb{1}\{\text{posted a question}\}_{ia} \times \tau_{ia} + \beta^X X_{ia} + \varepsilon_{ia}.$$

where $\wedge \mathbf{b}_{-i,a}$ is the best bid among opponents and $\tau_{ia} \in [0,1]$ denotes the timing of the question posting.[11] The control variables X_{ia} include auction-level characteristics and number of questions posted by opponents. We normalize the period at which firms can post questions to the interval $[0,1]$. We expect $\beta_1 > 0$, $\beta_2 < 0$, and $\beta_1 + \beta_2 < 0$ for our estimates to be consistent with the hypothesis presented above.

Table 3 reports the results from this regression. First, we observe that firms who post questions at $t = 0$ face a weaker best bid from opponents compared to those who never post by 5.8% of the engineer's estimate ($\beta_1 > 0$). Second, firms that post questions at $t = 0$ face a weaker best bid from opponents compared to those who post at $t = 1$ by 7.2% of the engineer's estimate ($\beta_2 < 0$). Third, our point estimates suggest that firms who post questions at $t = 1$ face a stronger best bid from opponents than those who never post by 1.4% of the engineer's estimate ($\beta_1 + \beta_2 < 0$), although the relation is not statistically significant.

These results are consistent with the hypothesis that: early disclosures are beneficial because there is a strong enough deterrent effect; and late disclosures are detrimental as they lead other entrants bid more aggressively while the deterrent effect becomes weak.

Fact 3: Questions from opponents and bid

Suppose again that questions serve as an entry disclosure. If firms incorporate the disclosures into their bids, they are likely to be placing stronger bids if they observe

[11] The sample for this regression is the entrants who had at least one competing entrant.

Table 3: Timing of questions and best bid from opponent

Dependent variable: Best bid from opponent		
	Coefficient	Standard Error
Posted a Q	0.058	0.030
Timing of Q: τ	-0.072	0.040
Controls	Yes	
N	1,144	

Note: Estimation is based on the sample: entrants who had at least one opponent. Standard errors are clustered at the auction level.

disclosures from opponents. To assess the relationship between presence of questions from opponents and a firm's bid, we run the following regression:

$$b_{i,a} = \beta_0 + \beta_1 \mathbb{1}\{\text{\# questions from opponents}\}_{ia} + \beta^X X_a + \varepsilon_{ia},$$

where we control for auction-level characteristics X_a.

We find that $\hat{\beta}_1 = -0.039$ (S.E. = 0.013), which is consistent with our hypothesis.[12] Firms facing more questions from opponents tend to submit stronger bids compared to those who facing fewer questions; in fact, seeing one additional question corresponds to placing a stronger bid by 3.9% of the engineer's estimate. This pattern reinforces our hypothesis that questions function as entry disclosures and that firms incorporate this information into their bidding behavior.

Discussion

One may consider an alternative hypothesis: if there is unobserved heterogeneity in the quality (or uncertainty) of the government's proposal across projects and the presence/number of questions acts as a proxy for such quality, we may observe the same pattern as Fact 1. Now, suppose that the presence/number of questions do act as a proxy for quality of the proposals. Then, we would see weaker bids in auctions where questions are posted. However, our findings indicate the opposite trend. While Fact 3

[12] Adding in a dummy variable for firm i posting a question and/or firm i's timing of question posting does not change our estimate in a meaningful way.

partly addresses this concern, we run the following regression:

$$b_{i,a} = \beta_0 + \beta_1 \mathbb{1}\{\#\text{total questions}\}_a + \beta^X X_a + \varepsilon_{ia}.$$

Our estimate is $\hat{\beta}_1 = -0.025$ (S.E. $= 0.011$), suggesting that the level of bids are stronger in auctions with greater number of questions. This suggests that unobserved heterogeneity in quality of proposals does not seem to be a primary concern in our analysis.

Another alternative hypothesis may posit that if firms who have lower costs tend to arrive earlier, we may observe the same pattern to that described as Fact 2. However, it is important to note that this hypothesis alone cannot explain Fact 1. To further explore this point, although with parametric assumptions, we can estimate the construction costs of each firm without imposing structure on how decisions on entry and question posting are made. We consider two scenarios when we estimate the construction costs for this practice: (i) firms condition their bidding strategies on the question postings; and (ii) firms do not condition their strategies on any question postings.We run the following regression:

$$\hat{c}_{ia} = \beta_0 + \beta_1 \tau_{ia} + \beta^X X_a + \varepsilon_{ia}.$$

where the sample consists of firms that posted a question, $\hat{c}_{ia}$ is the estimated cost, and τ_{ia} is the timing of question posted. If this hypothesis significantly influences the data, we would expect to see $\beta_1 < 0$. However, our estimates under both scenarios do not support this pattern, where $\hat{\beta}_1 = 0.017$ (S.E. $= 0.081$) for scenario (i) and $\hat{\beta}_1 = 0.016$ (S.E. = 0.079) for scenario (ii). Therefore, we do not consider this hypothesis to be a primary driver of our data.

5 Identification

In this section, we provide a discussion on identification of the model. We identify the model primitives in a sequential manner through the six steps outlined below. The primitives we aim to identify include: the distribution of arrival timing F_τ, entry costs F_E, disclosure costs F_Q, construction costs F_c, each entrant's construction cost c_i and the probability of forced disclosure p^Q. Construction costs are identified from the bidding stage, while the other primitives are identified from variation in entry and disclosure behaviors. It is worth emphasizing that entry timing τ_i is observed for the firms that disclose, but not for the firms that do not disclose.

While the discussion below holds even when conditioning on auction-level characteristics, we omit such expressions for the sake of exposition. Moreover, all the distributions we aim to identify are identified at the firm level. In what follows, we may omit the firm-level index as well.

Step 1. Construction costs c_i and its distribution F_{c_i} First, we aim to identify the construction costs c_i of each bidder and the distribution F_{c_i}. The argument follows the strategy established by Guerre et al. (2000). We impose the following assumption on bidders' strategies:

Assumption 1. *Firm i's bidding strategy is strictly increasing in their construction costs c_i, conditional on the entire disclosure history h^T.*

For each public history h^T, the bidder i's problem at the bidding stage is to maximize their expected value $V_i(h^T, c_i)$:

$$V_i(h^T, c_i) = \max_b (b - c_i) G_{-i}(b|h^T), \tag{5.1}$$

where $G_{-i}(b|h^T)$ denotes the distribution of the lowest rival bid, $\wedge \mathbf{b}_{-i}$, conditional on h^T. Note that $G_{-i}(\cdot|h^T)$ is nonparametrically identified, and thus $F_c(c_i|h^T)$ is identified by exploting the first order condition of this problem. Moreover, $F_{c_i}(c)$ is identified by pooling across all realizations of h^T:

$$F_{c_i}(c) = \Pr(c_i \leq c) = \int F_{c_i}(c|h^T) dF_{\mathscr{H}^T}(h^T). \tag{5.2}$$

Note that the right-hand side of (5.2) is the probability that c_i is less than c without conditioning on h^T (but conditional on i bidding in the auction). The distribution, $F_{\mathscr{H}^T}$, is the distribution of time-T history h^T in $\mathscr{H}^T$, which is the set of all possible time-T histories.

Step 2. Beliefs on history evolution $h^{\tau_i} \to h^T$ Next, we identify the belief of firm i on time-T history h^T conditional on the history at entry timing h^{τ_i} and disclosure action

a_i^Q. We denote such belief as $\mu_i(h^T|h^\tau, \tau_i = \tau, a_i^Q)$.

When firm i discloses, their belief is directly identified from the data. However, when firm i does not disclose, their belief cannot be directly identified from data because there is a selection issue due to the fact that their entry timing is not observed. In this case, the key idea for identification is to think of this setup as a survival analysis, where the event is a disclosure from a firm. Additionally, the possibility of multiple firms disclosing can be treated as competing risks. Following this idea, we can establish a simple mapping from the observed evolution of disclosure histories to a firm's belief about the evolution. It has been shown that the hazard function for each risk can be identified, if potential survival times of each risk are mutually independent (Tsiatis 1975). In our context, this corresponds to identifying each firm's hazard function for disclosing, given any history. We can then identify the belief of a firm on how the disclosure history would evolve.

For the sake of simplicity, we provide an argument for the symmetric case. The proof that allows for asymmetry is given in Appendix Section A. First, consider the following probability $p^{noQ}(\tau^1, \tau^2|h^{\tau^1})$:

$$p^{noQ}(\tau^1, \tau^2|h^{\tau^1}) = \Pr(\text{no disclosure between time } \tau^1 \text{ and } \tau^2|h^{\tau^1})$$

where $\tau^1 < \tau^2$. Let the number of firms who have not disclosed under h^{τ^1} be M. Moreover, let the firms who have disclosed by τ^1 be $j_1, \ldots, j_J$, with their corresponding timings $\tilde{\tau}_1, \ldots, \tilde{\tau}_J$. We can express this probability as follows:

$$\begin{aligned}
p^{noQ}(\tau^1, \tau^2|h^{\tau^1}) &= \frac{\Pr(h^{\tau^2})}{\Pr(h^{\tau^1})} \\
&= \frac{\prod_{m=1}^{J} \int_0^\infty f_\tau(\tilde{\tau}_m) A^{\tilde{\tau}_m}(h^{\tau_m}(\tilde{\tau}_1, \ldots, \tilde{\tau}_{m-1}), c) f_c(c)}{\prod_{m=1}^{J} \int_0^\infty f_\tau(\tilde{\tau}_m) A^{\tilde{\tau}_m}(h^{\tau_m}(\tilde{\tau}_1, \ldots, \tilde{\tau}_{m-1}), c) f_c(c)} \\
&\quad \times \frac{\left\{1 - F_\tau(\tau^2) + \int_0^\infty \int_0^{\tau^2} f_\tau(t)(1 - A^t(h^{\tau_2}, c)) f_c(c) dt\, dc\right\}^M}{\left\{1 - F_\tau(\tau^1) + \int_0^\infty \int_0^{\tau^1} f_\tau(t)(1 - A^t(h^{\tau^1}, c)) f_c(c) dt\, dc\right\}^M} \\
&= \frac{\left\{1 - F_\tau(\tau^2) + \int_0^\infty \int_0^{\tau^2} f_\tau(t)(1 - A^t(h^{\tau_2}, c)) f_c(c) dt\, dc\right\}^M}{\left\{1 - F_\tau(\tau^1) + \int_0^\infty \int_0^{\tau^1} f_\tau(t)(1 - A^t(h^{\tau^1}, c)) f_c(c) dt\, dc\right\}^M}
\end{aligned}$$

where h^{τ_2} is a history that includes the same set of disclosures as h^{τ_1} and has no disclosures between τ_1 and τ_2. The probability of entering and disclosing under history h and construction cost c, $A^t(h,c)$ is:

$$A^t(h,c) \equiv F_E(V^t(h))\big(p^Q + (1-p^Q)F_Q(\Delta v_i^t(h,c)\big)$$

with $V^t(h)$ represents the value of entry at time t conditional on history h, and $\Delta v_i^t(h,c)$ is the value of disclosure at time t conditional on history h and construction cost c.[13]

Now, let us consider the belief of a firm i on the same object when the firm enters but does not disclose at τ $(\tau \le \tau_1 < \tau_2)$. We denote such belief as $\mu_i^{noQ}(\tau_1,\tau_2|h^{\tau_1},\tau_i = \tau, a_i^Q = 0)$. Then,

$$\begin{aligned}
\mu_i^{noQ}(\tau_1,\tau_2|h^{\tau_1},\tau_i=\tau,a_i^Q=0) &= \frac{\Pr(h^{\tau^2}\cap\{\tau_i=\tau,a_i^Q=0\})}{\Pr(h^{\tau^1}\cap\{\tau_i=\tau,a_i^Q=0\})} \\
&= \frac{\int_0^\infty F_E(V^\tau(h^\tau))\big(1-\big(p^Q+(1-p^Q)F_Q(\Delta v(h^\tau,c))\big)\big)f_c(c)dc}{\int_0^\infty F_E(V^\tau(h^\tau))\big(1-\big(p^Q+(1-p^Q)F_Q(\Delta v(h^\tau,c))\big)\big)f_c(c)dc} \\
&\times \quad \frac{\prod_{m=1}^J\int_0^\infty f_\tau(\tilde\tau_m)A^{\tilde\tau_m}(h^{\tau_m}(\tilde\tau_1,\dots,\tilde\tau_{m-1}),c)f_c(c)dc}{\prod_{m=1}^J\int_0^\infty f_\tau(\tilde\tau_m)A^{\tilde\tau_m}(h^{\tau_m}(\tilde\tau_1,\dots,\tilde\tau_{m-1}),c)f_c(c)dc} \\
&\times \frac{\left\{1-F_\tau(\tau^2)+\int_0^\infty\int_0^{\tau^2}f_\tau(t)(1-A^t(h^{\tau_2},c))f_c(c)dtdc\right\}^{M-1}}{\left\{1-F_\tau(\tau^1)+\int_0^\infty\int_0^{\tau^1}f_\tau(t)(1-A^t(h^{\tau^1},c))f_c(c)dtdc\right\}^{M-1}} \\
&= \frac{\left\{1-F_\tau(\tau^2)+\int_0^\infty\int_0^{\tau^2}f_\tau(t)(1-A^t(h^{\tau_2},c))f_c(c)dtdc\right\}^{M-1}}{\left\{1-F_\tau(\tau^1)+\int_0^\infty\int_0^{\tau^1}f_\tau(t)(1-A^t(h^{\tau^1},c))f_c(c)dtdc\right\}^{M-1}}
\end{aligned}$$

holds. Note that firm i's knowledge of its own construction cost does not affect this belief.

As we can see, there is a simple relationship between the observed probability $p^{noQ}(\tau^1,\tau^2|h^{\tau^1})$ and belief $\mu_i^{noQ}(\tau_1,\tau_2|h^{\tau_1},\tau_i=\tau,a_i^Q=0)$. The former can be expressed as q^M, while the latter is expressed as q^{M-1}, where q is some number. Thus,

$$\mu_i^{noQ}(\tau_1,\tau_2|h^{\tau_1},\tau_i=\tau,a_i^Q=0) = p^{noQ}(\tau^1,\tau^2|h^{\tau^1})^{\frac{M-1}{M}} \tag{5.3}$$

[13]Formally, if history h contains information up to time t' $(t' > t)$, we are conditioning on the restricted history $h^t|h^{t'}$ that contains the same information as $h^{t'}$ but only those that happen before t.

holds. Since the right hand side is directly identified from data, i's belief on having no disclosures between two time points is identified. Therefore, i's belief on time-T history for the case where firm i does not disclose is identified as well.

Step 3. Value of disclosure We argue that the value of disclosure is identified. The expected value, $v_i^{1,\tau}(h^\tau, c_i)$, from disclosing at time τ under history h^τ when i's construction cost is c_i is simply

$$v_i^{1,\tau}(h^\tau, c_i) = \int V_i(h^T, c_i)\, \mu_i(h^T | h^\tau, \tau_i = \tau, a_i^Q = 1)\, dh^T, \tag{5.4}$$

where $V_i(h^T, c_i)$ is the value from the bidding stage and is given by expression (5.1). For each time-T history h^T, the expected value of bidder i with cost realization c_i is $V_i(h^T, c_i)$. By integrating $V_i(h^T, c_i)$ with respect to $\mu_i(h^T | h^\tau, \tau_i = \tau, a_i^Q)$, the belief on distribution over possible time-T histories, we obtain the expected value. Similarly, the expected value, $v_i^{0,\tau}(h^\tau, c_i)$, from *not* disclosing at time τ under history h^τ when construction cost is c_i is

$$v_i^{0,\tau}(h^\tau, c_i) = \int V_i(h^T, c_i)\, \mu_i(h^T | h^\tau, \tau_i = \tau, a_i^Q = 0)\, dh^T. \tag{5.5}$$

Note that $V_i(h^T, c_i)$ is identified for all time-T histories h^T and construction costs c_i in Step 1, and μ_i was identified in Step 2. Therefore, the terms on the right-hand sides of equations (5.4) and (5.5) are all identified, establishing that $v_i^{1,\tau}(h^\tau, c_i)$ and $v_i^{0,\tau}(h^\tau, c_i)$ are both identified. We denote the value of disclosure as $\Delta v_i^\tau(h^\tau, c_i) \equiv v_i^{1,\tau}(h^\tau, c_i) - v_i^{0,\tau}(h^\tau, c_i)$, which confirms that the value of disclosure is identified.

Step 4. Probability of forced disclosure p^Q and distribution of disclosure costs F_Q First, we introduce the following assumption:

Assumption 2. *Support of disclosure values is $[\underline{v^Q}, \overline{v^Q}]$. Firms always disclose at the upper bound of the disclosure value: $F_Q(\overline{v^Q}) = 1$.*

The key variation we leverage here is the difference in disclosure values across firms with varying construction costs but those who are facing the same disclosure history.

When a firm is not forced to disclose, the decision to disclose is given by the following expression:

$$\begin{cases} \iota_{i,\tau}(h^\tau, c_i, c_i^Q) = 1 & \text{if } \Delta v_i^\tau(h^\tau, c_i) \geq c_i^Q \\ \iota_{i,\tau}(h^\tau, c_i, c_i^Q) = 0 & \text{otherwise} \end{cases} \tag{5.6}$$

The expected value of the auction $\tilde{v}_i^\tau(h^\tau, c_i)$ at time τ under history h^τ and costs c_i is:

$$\tilde{v}_i^\tau(h^\tau, c_i) = p^Q v_i^1(h^\tau, c_i) + (1-p^Q)\mathbb{E}_{F^Q}\left[\max\left\{v_i^0(h^\tau, c_i), v_i^1(h^\tau, c_i) - c_i^Q\right\}\right]. \tag{5.7}$$

The first term corresponds to the case where firm i is forced to disclose. Inside the expectation bracket, the first term represents the expected value from not disclosing, and the second term represents the expected value from disclosing. The expected value of entry, $v_i(h^\tau)$, is then

$$v_i^\tau(h^\tau) = \mathbb{E}_{F_{c_i}}\left[\tilde{v}_i^\tau(h^\tau, c_i)\right]. \tag{5.8}$$

The decision to enter at time τ under history h^τ is given by the following expression:

$$\begin{cases} \chi_{i,\tau}(h^\tau, c_i^E) = 1 & \text{if } v_i^\tau(h^\tau) \geq c_i^E \\ \chi_{i,\tau}(h^\tau, c_i^E) = 0 & \text{if otherwise} \end{cases} \tag{5.9}$$

Fix values $v', v'' \in \mathbb{R}$. Recall that the expected gain from disclosure, $\Delta v_i^\tau(h^\tau, c_i)$, is identified for all τ, h^τ and c_i. Now let us take c_i' and c_i'' appropriately so that $\Delta v(h^\tau, c_i') = v'$ and $\Delta v(h^\tau, c_i'') = v''$ for some h^τ. The density that a firm with type c_i' discloses at h^τ is given by:

$$\begin{aligned} f\left(a_i^Q = 1, \tau_i = \tau, h^\tau, c_i'\right) &= f_{\mathcal{H}^\tau}(h^\tau | c_i', \tau_i = \tau)\, f_\tau(\tau)\, f_{c_i}(c_i')\, F_E(v_i^\tau(h^\tau))\left(p^Q + (1-p^Q)F_Q(v')\right) \\ &= f_{\mathcal{H}^\tau}(h^\tau | \tau_i = \tau)\, f_\tau(\tau)\, f_{c_i}(c_i')\, F_E(v_i^\tau(h^\tau))\, \tilde{F}_Q(v') \end{aligned} \tag{5.10}$$

where $f_{\mathcal{H}^\tau}$, f_τ and f_c are the densities of $F_{\mathcal{H}^\tau}$, F_τ and F_c, respectively. Also, we denote $\tilde{F}_Q(v) = \left(p^Q + (1-p^Q)F_Q(v)\right)$. The first term on the right-hand side of (5.10) is the probability that event h^τ occurs conditional on arrival timing τ_i being equal to τ. The second term is the probability of τ_i being equal to τ, and the third term gives the probability that the cost draw is c_i'. The fourth term corresponds to the entry probability. Finally, the last term represents the probability of disclosure ($a_i^Q = 1$) conditional on time-τ history h^τ and construction cost c_i'. This final probability accounts for (i) forced disclosure and (ii) costly disclosure if the disclosure cost, c_i^Q, is less than v', i.e., $c_i^Q \le \Delta v_i^{\tau}(h^{\tau}, c_i')(= v')$.

Similarly, the density that a firm with type c_i'' discloses under history h^{τ} is as follows:

$$\Pr\left(a_i^Q = 1, \tau_i = \tau, h^{\tau}, c_i''\right) \;=\; f_{\mathscr{H}^{\tau}}(h^{\tau}|\tau_i = \tau)\, f_{\tau}(\tau)\, f_{c_i}(c_i'')\, F_E(v_i(h^{\tau}))\, \tilde{F}_Q(v''). \tag{5.11}$$

Since construction costs c_i are identified for all entrants from Step 1, the left-hand sides of expressions (5.10) and (5.11) are both identified. Moreover, $f_c(c_i')$ and $f_c(c_i'')$ are both identified because $F_{c_i}(c)$ is identified. Hence, from the ratio of expressions (5.10) and (5.11), we identify $\tilde{F}_Q(v')/\tilde{F}_Q(v'')$. Because F_Q is a distribution, p^Q and F_Q are identified.[14][15]

Step 5. Value of entry As demonstrated in (5.12), value of entry $v_i^{\tau}(h^{\tau})$ can be expressed as:

$$\begin{aligned}
v_i^{\tau}(h^{\tau}) &= \mathbb{E}_{F_{c_i}}\left[\tilde{v}_i^{\tau}(h^{\tau}, c_i)\right] \\
&= \int \tilde{v}_i^{\tau}(h^{\tau}, c_i) dF_{c_i}(c_i) \\
&= \int p^Q v_i^{1,\tau}(h^{\tau}, c_i) + (1-p^Q)\mathbb{E}_{F^Q}\left[\max\left\{v_i^{0,\tau}(h^{\tau}, c_i), v_i^{1,\tau}(h^{\tau}, c_i) - c_i^Q\right\}\right] dF_{c_i} \\
&= \iint p^Q v_i^{1,\tau}(h^{\tau}, c_i) + (1-p^Q)\max\left\{v_i^{0,\tau}(h^{\tau}, c_i), v_i^{1,\tau}(h^{\tau}, c_i) - c_i^Q\right\} dF_Q\, dF_{c_i}
\end{aligned}$$

Since all the objects that appear in this expression are identified objects, value of entry $v_i^{\tau}(h^{\tau})$ is also identified.

Step 6. Distribution of entry costs F_E and arrival timing F_{τ} In this final step, our goal

[14]If $\tilde{F}_Q(v')/\tilde{F}_Q(v'')$ is identified for all $v', v'' \in \mathbb{R}$, it implies that $\tilde{F}_Q(v)$ is identified up to a constant, say, $\tilde{F}_Q(0)$. This is because we can express $\tilde{F}_Q(v)$ as follows: $\tilde{F}_Q(v) = \tilde{F}_Q(0)\big(\tilde{F}_Q(v)/\tilde{F}_Q(0)\big)$, where the ratio $\big(\tilde{F}_Q(v)/\tilde{F}_Q(0)\big)$ is identified. There is a unique value of $\tilde{F}_Q(0)$ such that $\lim_{v \to \overline{v^D}} F_Q(v) = 1$.

[15]Strictly speaking, we need an assumption for this argument to be valid. We assume that: For all $(v', v'') \in [\underline{v^Q}, \overline{v^Q}]^2$, there exist a sequence of histories $(h_1^{\tau_1}, \ldots, h_H^{\tau_H})$ and a sequence of numbers $(v_1, \ldots, v_{H+1})$ such that (i) $v_1 = v'$; (ii) $v_{H+1} = v''$: and (iii) there exist some $c_{k,1}, c_{k,2} \in \mathbb{R}^+$ that $\Delta v_i^{\tau_k}(h^{\tau_k}, c_{k,1}) = v_k$ and $\Delta v_i^{\tau_k}(h^{\tau_k}, c_{k,2}) = v_{k+1}$ for all k $(1 \le k \le H)$.

is to identify the remaining two distributions: the entry cost distribution and arrival timing distribution. To achieve this, the idea is to exploit variation in value of entry and value of disclosure across firms facing different disclosure histories.

Suppose that under time-τ history h^τ, where bidders $j_1,\ldots,j_J$ have each disclosed at $\tau_{j_1},\ldots,\tau_{j_J}$ ($\tau_{j_1}<\cdots<\tau_{j_J}$), and the remaining bidders i and $k_1,\ldots,k_K$ have not disclosed. As in Step 2, let

$$A_i^t(h,c_i)\equiv F_E^i(V_i^t(h))F_Q(\Delta v_i^t(h,c_i)) \tag{5.12}$$

First, consider the following density P:[16]

$$\begin{aligned}
P &= \Pr\big(j_m \text{ signals at } \tau_{j_m}\,\forall m, i \text{ signals at } \tau, k_n \text{ does not signal before } \tau\,\forall n,\ \vec{c}_j, c_i\big)\\
&= \prod_m f_\tau^{j_m}(\tau_{j_m})A_{j_m}^{\tau_{j_m}}(h^{\tau_{j_m}}(\tau_{j_1},\ldots,\tau_{j_J}),c_{j_m})f_{c_{j_m}}(c_{j_m})\\
&\times\prod_n\left\{1-F_\tau^{k_n}(\tau)+\int_0^\infty\int_0^\tau f_\tau^{k_n}(t)\Big(1-A_{k_n}^t(h^t(\tau_{j_1},\ldots,\tau_{j_J}),c_{k_n})\Big)f_{c_{k_n}}(c_{k_n})dt\,dc_{k_n}\right\}\\
&\times f_\tau^i(\tau)A_i^\tau(h^\tau(\tau_{j_1},\ldots,\tau_{j_J}),c_i)f_{c_i}(c_i)
\end{aligned} \tag{5.13}$$

Next, We consider the following density Q:

$$\begin{aligned}
Q &= \Pr\big(j_m \text{ signals at } \tau_{j_m}\,\forall m, i \text{ does not signal before } \tau, k_n \text{ does not signal before } \tau\,\forall n,\ \vec{c}_j, c_i\big)\\
&= \prod_m f_\tau^{j_m}(\tau_{j_m})A_{j_m}^{\tau_{j_m}}(h^{\tau_{j_m}}(\tau_{j_1},\ldots,\tau_{j_J}),c_{j_m})f_{c_{j_m}}(c_{j_m})\\
&\times\prod_n\left\{1-F_\tau^{k_n}(\tau)+\int_0^\infty\int_0^\tau f_\tau^{k_n}(t)\Big(1-A_{k_n}^t(h_t(\tau_{j_1},\ldots,\tau_{j_J}),c_{k_n})\Big)f_{c_{k_n}}(c_{k_n})dt\,dc_{k_n}\right\}\\
&\times\left\{1-F_\tau^i(\tau)+\int_0^\infty\int_0^\tau f_\tau^i(t)\big(1-A_i^t(h^t(\tau_{j_1},\ldots,\tau_{j_J}),c_i)\big)f_{c_i}(c_i)dt\,dc_i\right\}.
\end{aligned} \tag{5.14}$$

Taking the ratio between these two densities gives us:

$$P/Q=\frac{f_\tau^i(\tau)A_i^\tau(h^\tau(\tau_{j_1},\ldots,\tau_{j_J}),c_i)f_{c_i}(c_i)}{\left\{1-F_\tau^i(\tau)+\int_0^\infty\int_0^\tau f_\tau^i(t)\big(1-A_i^t(h^t(\tau_{j_1},\ldots,\tau_{j_J}),c_i)\big)f_{c_i}(c_i)dt\,dc_i\right\}} \tag{5.15}$$

[16]When we write $h^t(\tau_{j_1},\ldots,\tau_{j_J})$, this is a time-$t$ history such that disclosures are made at times that are in the set $\{\tau_{j_1},\ldots,\tau_{j_J}\}$ and before t. Note that we are also suppressing the expression on which firm disclosed at which timing.

Exploiting the relation that

$$\frac{\partial\left(1-F_\tau^i(\tau)+\int_0^\infty\int_0^\tau f_\tau^i(t)\left(1-A_i^t(h^t,c_i)\right)f_c(c_i)\,dt\,dc_i\right)}{\partial\tau}=-\int_0^\infty f_\tau^i(\tau)A_i^\tau(h^\tau(\tau_{j_1},\ldots,\tau_{j_J}),c_i)f_c(c_i)\,dc_i,$$

the function

$$\begin{aligned}\Gamma_i(\tau;h^\tau=(\tau_{j_1},\ldots,\tau_{j_J}))&=1-F_\tau^i(\tau)+\int_0^\infty\int_0^\tau f_\tau^i(t)\left(1-A_i^t(h^t,c_i)\right)f_c(c_i)\,dt\,dc_i\\&=1-\int_0^\infty\int_0^\tau f_\tau^i(t)A_i^t(h^t,c_i)f_c(c_i)\,dt\,dc_i\end{aligned}\tag{5.16}$$

is identified up to scale for all $\tau\in[\tau_{j_J},T]$.[17] And thus

$$\begin{aligned}-\frac{\partial\Gamma_i}{\partial\tau}(\tau;(\tau_{j_1},\ldots,\tau_{j_J}))&=\int_0^\infty f_\tau^i(\tau)A_i^\tau(h^\tau(\tau_{j_1},\ldots,\tau_{j_J}),c_i)f_c(c_i)\,dc_i\\&=f_\tau^i(\tau)F_E^i(V_i^\tau(h^\tau(\tau_{j_1},\ldots,\tau_{j_J})))\int_0^\infty F_Q(\Delta v_i^\tau(h^\tau(\tau_{j_1},\ldots,\tau_{j_J}),c_i))f_c(c_i)\,dc_i\end{aligned}$$

is identified up to scale. Since $\Gamma_i(0;h^0=\phi)$=1 holds, $\Gamma_i(\tau;h^\tau=\phi)$ is identified for all $\tau\in[0,T]$.[18] Therefore, $\frac{\partial\Gamma_i}{\partial\tau}(\tau;h^\tau=\phi)$ is identified for all $\tau\in[0,T]$. Furthermore, since F_Q is identified, $f_\tau^i(\tau)F_E^i(V_i^\tau(h^\tau=\phi))$ is identified for all $\tau\in[0,T]$.

Now, given that $f_\tau^i(\tau)F_E^i(V_i^\tau(\phi))$ is identified, $f_\tau^i(t)A_i^t(h^t=\phi,c_i)$ is identified for all $t\in[0,T]$. Consequently, as Γ_i is expressed as (5.16), $\Gamma_i(\tau;h^\tau=\tau)$ is identified. Since Γ_i is identified up to scale and now that $\Gamma_i(\tau;h^\tau=\tau)$ is identified, $\Gamma_i(\tau';h^{\tau'}=\tau)$ is identified for all $\tau'\in[\tau,T]$. As a result, $f_\tau^i(t)\ F_E^i(V_i{}^t(h^t))$ such that h^t includes one disclosure is identified. By induction on the number of disclosures made, repeating this argument will allow us to identify $f_\tau^i(\tau)\ F_E^i(V_i{}^\tau(h^\tau))$ for all histories h^τ.

To proceed with the identification of f_τ, fix $\tau',\tau''\in[0,T]$ and take $h^{\tau'}$ and $h^{\tau''}$ appropriately so that $V_i^{\tau'}(h^{\tau'})=V_i^{\tau''}(h^{\tau''})=v$ for some constant $v\in\mathbb{R}$. We identify the ratio, $f_\tau(\tau')/f_\tau(\tau'')$ from the ratio of $f_\tau^i(\tau')F_E^i(V_i^{\tau'}(h^{\tau'}))$ and $f_\tau^i(\tau'')F_E^i(V_i^{\tau''}(h^{\tau''}))$. Since F_τ is a distribution, F_τ is identified.[19]

[17] Note that $\frac{dF(x)}{dx}/F(x)=\frac{d(\log F(x))}{dx}$ holds. If the left-hand side object is identified, $\log F(x)$ is identified up to a constant. Therefore, $F(x)$ is identified up to scale.

[18] When we write $h^t=\phi$, we mean that time-t history h^t does not include any disclosures.

[19] Strictly speaking, we need an assumption for this argument to be valid. We assume that: For all

Finally, since f_τ and $f_\tau^i(\tau)F_E^i(V_i^\tau(h^\tau))$ are identified, F^E is also identified.

6 Estimation

In this section, we provide an outline of the estimation procedure, which closely follows the identification argument.

6.1 Parametric assumptions

To apply our model to data, we introduce parametric assumptions, despite having established non-parametric identification. First, we assume that firms are *ex-ante* symmetric, conditional on auction-level characteristics: all the firms share the same distribution for entry timing, entry costs, disclosure costs, and construction costs if the auction is the same construction type and from the same district.

In what follows, we set $T = 1$. We specify parametric forms for the distributions of entry timing, entry costs, and disclosure costs. We assume that the distribution of entry timing follows a Beta distribution with two shape parameters $\theta^\tau \equiv (\alpha_\tau, \beta_\tau)$, which lies within the interval $[0,1]$. Next, we make the following assumption on entry costs. With probability p^E, each firm gets a chance to consider whether they would enter an auction, while a firm always stays out with the other probability $1-p^E$. This reflects the fact that firms may face various constraints, such as other ongoing projects. If a firm considers entry, they draw an entry cost c_i^E from a truncated normal distribution on $[0,\infty)$ with parameters $\theta^E \equiv (\mu_E, \sigma_E)$. Here, we parameterize $\mu_E = X_a\beta^E + \alpha^E$, where X_a is the logarithm of number of potential entrants. Finally, we assume that the distribution of disclosure costs F_Q follows a truncated normal distribution on $[0,\infty)$ with parameters $\theta^Q \equiv (\mu_Q, \sigma_Q)$. Note that we have also assumed that firms are in a position where they must disclose with probability p^Q, reflecting the fact that disclosures are done through posting questions in our setup.

$(\tau', \tau'') \in [0,T]^2$, there exist a sequence of timings $(\tau^1, \ldots, \tau^H)$ and a sequence of numbers $(v_1, \ldots, v_H)$ such that (i) $\tau^1 = \tau'$; (ii) $\tau^H = \tau''$: and (iii) there exist some histories h^{τ_k} and $\tilde{h}^{\tau_{k+1}}$ such that $V_i^{\tau_k}(h^{\tau_k}) = V_i^{\tau_{k+1}}(h^{\tau_{k+1}})$ for all k $(1 \le k \le H-1)$.

6.2 Estimation procedure

We estimate our parameters in four steps. In the first step, we start by estimating the construction costs for each entrant and the distribution of such costs, exploiting the bidding results. Next, we estimate firms' beliefs on how disclosure history evolves over time, conditional on their disclosure actions. With the estimates from the bidding stage and estimated beliefs on disclosure history, we turn to the estimation of the value of disclosure and entry. Finally, using the obtained estimates, we estimate the remaining model primitives via maximum likelihood estimation.

Step 1. Construction costs c_i To account for the fact that some bids are ultimately rejected, we assume the presence of a secret reserve price p^r, which follows a log-normal distribution. To estimate the construction costs c_i, we exploit the optimality of the bids as in Guerre et al. (2000). Specifically, construction cost c_i when the bid is b_i is estimated exploiting the first order condition for bidding:

$$c_i = b_i - \frac{1 - G_{-i}(b)}{g_{-i}(b)} \tag{6.1}$$

where G_{-i} is the CDF of the lowest bid among the opponents, and g_{-i} is the corresponding pdf.[20]

We assume that G_{-i} follows a log-normal distribution log-$\mathcal{N}(\mu_b, \sigma_b)$ with:

$$\mu_b = \mathbf{X}_\mathbf{i}^{\mu_\mathbf{b}} \beta^{\mu_\mathbf{b}}, \qquad \sigma_b = \mathbf{X}_\mathbf{i}^{\sigma_\mathbf{b}} \beta^{\sigma_\mathbf{b}},$$

where $X_i^{\mu_b}$ includes a dummy indicating whether i disclosed, the time at which i disclosed, the number of disclosures made by others, the number of potential bidders, construction type dummies, and district dummies. For the variance, $X_i^{\sigma_b}$ includes the number of others' disclosures, the number of potential bidders, construction type dummies, and district dummies. We estimate the parameters $(\beta^{\mu_b}, \sigma^{\mu_b})$ via maximum likelihood estimation. Once we obtain the estimates for the distribution G_{-i}, we exploit (6.1) and estimate construction costs for each entrant. While we allow the distribution of construction costs F_c to be fully nonparametric, we assume that the distribution

[20] This will be the minimum of the opponents' bid and the secret reserve price.

depends on the type of construction and district at which the project is located.

Step 2. Belief on the evolution of disclosure history Closely following the identification argument, we start by estimating the observed evolution of disclosure histories. Let us note here again that the observed evolution of disclosure histories and the beliefs on the histories are not identical. We parameterize the distribution of time intervals between the n-th and $(n+1)$-th disclosure as follows (time interval between $t=0$ and the first disclosure will be also included as case $n=0$):

$$\Pr(\tau^{n+1}-\tau^{n}\leq x)=\frac{\Phi((x-\mu_t)/\sigma_t)-\Phi(-\mu_t/\sigma_t)}{1-\Phi(-\mu_t/\sigma_t)}$$

if the $(n+1)$-th disclosure exists and

$$\Pr((n+1)\text{-th disclosure does not exist})=\frac{1-\Phi(((1-\tau^{n})-\mu_t)/\sigma_t)}{1-\Phi(-\mu_t/\sigma_t)}$$

where timing of the n-th disclosure is given by τ^n.[21][22] The parameters (μ_t,σ_t) are characterized as:

$$\mu_t=\mathbf{X}^{\mu_t}\beta^{\mu_t},\qquad \sigma_t=\mathbf{X}^{\sigma_t}\beta^{\sigma_t},$$

where X^{μ_t} includes the n-th disclosure timing τ^n, the number of disclosures n, the log of (number of firms who have not disclosed yet $+1$), construction type dummies, and district dummies. For the variance, X^{σ_t} includes the number of disclosures n, and the log of (number of firms who have not disclosed yet $+1$). We estimate $(\beta^{\mu_t},\sigma^{\mu_t})$ via maximum likelihood.

Next, we turn to the estimation of the beliefs of the firms. First, we estimate the belief of a firm when the firm discloses at some time τ facing history h^τ. To estimate this belief, we simulate the evolution of the disclosure history, using the distribution of time intervals between disclosures we have estimated above. Suppose that i's disclosure was the n-th one. Then, the next disclosure timing τ^{n+1}'s distribution is characterized by the above distribution we have estimated. By repeating this process, until we draw

[21] We are implicitly assuming that the decision to disclose depends on the number of disclosures that have occurred up to that time and the timing of the most recent disclosure.

[22] If n is equal to the number of total potential bidders N, then the next disclosure does not exist with probability one.

the probability of next disclosure not existing, we can obtain the distribution of time-T histories. We denote the estimated belief as: $\hat{\mu}_i(h^T|h^\tau, \tau_i = \tau, a_i^Q = 1)$.

Next, we estimate a firm's belief when it enters but does not disclose at time τ facing history h^τ. Let τ^n represent the most recent disclosure before τ, with $\tau^n = 0$ if none exists. We exploit the following relationship, which we have shown as equation 5.3:

$$\begin{aligned}&\Pr(\tau^{n+1} > t \text{ or } (n+1)\text{-th disclosure does not exist})^{(M-1)/M}\\&= \mu_i(\tau^{n+1} > t \text{ or } (n+1)\text{-th disclosure does not exist})\end{aligned}$$

where M is the number of potential entrants who have not disclosed at τ, including firm i. Moreover, from equation 5.3,

$$\begin{aligned}&\Pr(\tau^{n+k} > t \text{ or } (n+k)\text{-th disclosure does not exist} \,|\, (n+k-1)\text{-th disclosure is at } \tau^{n+k-1})^{(M-k)/(M-k+1)}\\&= \mu_i(\tau^{n+k} > t \text{ or } (n+k)\text{-th disclosure does not exist} \,|\, (n+k-1)\text{-th disclosure is at } \tau^{n+k-1})\end{aligned}$$

holds for all k $(1 \leq k \leq M-1)$ and all t $(\tau^{n+k-1} < t < 1)$. These relationships allow us to back out the distribution of time intervals between disclosures from firm i's perspective, since the left hand-side objects are what we had estimated at the beginning of Step 2. Now, we can simulate the evolution of disclosure history using i's belief on the timing of disclosures. We denote the estimated belief as: $\hat{\mu}_i(h^T|h^\tau, \tau_i = \tau, a_i^Q = 0)$.

Step 3. Value of disclosure In this step, we aim to obtain an estimate for the value of disclosures. First, we start by estimating the value from the bidding stage $V_i(h^T, c)$. For clarity, each objects are estimated for every construction type and district pair, although we omit these specific dependencies here for simplicity. We estimate the value from bidding conditional on time-T history $V_i(h^T, c)$ by:

$$\hat{V}_i(h^T, c) = \max_b (b-c)(1-\hat{G}_{-i}(b|h^T)),$$

where $\hat{G}_{-i}$ is the estimated CDF of the lowest bid from opponents.

Next, we estimate the values with and without disclosure, $v^{1,\tau}(h^\tau, c)$ and $v^{0,\tau}(h^\tau, c)$.

This value is estimated by:

$$\hat{v}^{j,\tau}(h^\tau, c) = \int \hat{V}_i(h^T, c)\,\hat{\mu}_i(h^T | h^\tau, \tau_i = \tau, a_i^Q = j)\,dh^T$$

for $j = 0, 1$. Note that although we have expressed this as an integration, due to our estimation procedure, $\hat{\mu}_i$ is a discrete distribution. Therefore, this turns out to be a summation, in practice. Then, value of disclosure $\Delta v^\tau(h^\tau, c)$ can be estimated as:

$$\widehat{\Delta v}^\tau(h^\tau, c) = \hat{v}^{1,\tau}(h^\tau, c) - \hat{v}^{0,\tau}(h^\tau, c).$$

Step 4. Model primitives In our final step, we estimate our model primitives–specifically, the distribution of entry timing F_τ, entry costs F_E and p^E, and disclosure costs F_Q and p^Q– using observed entry and disclosure data. Note that if we have estimates $\hat{p}^Q$ and $\hat{F}^Q$ for p^Q and F_Q, value of entry $v(h^\tau)$ can be estimated as:

$$\begin{aligned}
\hat{v}^\tau(h^\tau) &= \sum_c \int \hat{p}^Q \hat{v}^{1,\tau}(h^\tau, c) + (1-\hat{p}^Q)\mathbb{E}_{\hat{F}^Q}\left[\max\left\{\hat{v}^{0,\tau}(h^\tau, c), \hat{v}^{1,\tau}(h^\tau, c) - c^Q\right\}\right] d\hat{F}_Q \\
&= \sum_c \Big[\big(\hat{p}^Q + (1-\hat{p}^Q)\hat{F}_Q(\max\{\hat{v}^{1,\tau}(h^\tau, c) - \hat{v}^{0,\tau}(h^\tau, c), 0\})\big)\,\hat{v}^{1,\tau}(h^\tau, c) \\
&\quad + (1-\hat{p}^Q)\big(1 - \hat{F}_Q(\max\{\hat{v}^{1,\tau}(h^\tau, c) - \hat{v}^{0,\tau}(h^\tau, c), 0\})\big)\,\hat{v}^{0,\tau}(h^\tau, c) \\
&\quad - (1-\hat{p}^Q)\int_0^{\max\{\hat{v}^{1,\tau}(h^\tau, c) - \hat{v}^{0,\tau}(h^\tau, c), 0\}} c^Q\, d\hat{F}_Q \Big].
\end{aligned} \tag{6.2}$$

where summation is taken over the estimated costs c.

Using this expression, we estimate the model primitives via maximum likelihood. Suppose firms $i_1, \ldots, i_I$ do not enter, firms $j_1, \ldots, j_J$ enter but do not disclose, and firms $k_1, \ldots, k_K$ enter and disclose at time $\tau_{k_1}, \ldots, \tau_{k_K}$. Also, let each entrant i's cost be c_i. Let this observation correspond to time-T history h^T. The likelihood function for observing this history h^T is:

$$\begin{aligned}\mathscr{L}(h^T) = \prod_l \int f_c(c_{i_l})dc \int f_\tau(t)(1-\tilde{F}_E(v(h^t)))dt \\ \times \prod_m f_c(c_{j_m}) \int f_\tau(t)\tilde{F}_E(v(h^t))(1-\tilde{F}_Q(\Delta v(h^t, c_{j_m})))dt \\ \times \prod_n f_c(c_{k_n}) f(\tau_{k_n})\tilde{F}_E(v(h^{\tau_{k_n}}))\tilde{F}_Q(\Delta v(h^{\tau_{k_n}}, c_{k_n})),\end{aligned}$$

where h^t and $h^{\tau_{k_n}}$ are time-t and time-τ_{k_n} histories that arise as a natural restriction of h^T. Furthermore, $\tilde{F}_E$ is defined as: $\tilde{F}_E = p^E F_E$. The parameters we aim to estimate here are: $\Theta \equiv (\theta^\tau, \theta^Q, p^Q, \theta^E, p^E)$. We solve:

$$\max_\Theta \sum_{a=1}^{A} \log \hat{\mathscr{L}}(h_a^T),$$

where $a = 1, \dots, A$ represents each auction, and

$$\begin{aligned}\hat{\mathscr{L}}(h^T) = \prod_l \int f_\tau(t;\theta^\tau)(1-\tilde{F}_E(\hat{v}(h^t;(\theta^Q, p^Q));(\theta^E, p^E)))dt \\ \times \prod_m \hat{f}_c(\hat{c}_{j_m}) \int f_\tau(t;\theta^\tau)\tilde{F}_E(\hat{v}(h^t;(\theta^Q, p^Q));(\theta^E, p^E))(1-\tilde{F}_Q(\widehat{\Delta v}^t(h^t, c_{j_m});(\theta^Q, p^Q)))dt \\ \times \prod_n \hat{f}_c(\hat{c}_{k_n}) f_\tau(\tau_{k_n};\theta^\tau)\tilde{F}_E(\hat{v}(h^{\tau_{k_n}};(\theta^Q, p^Q));(\theta^E, p^E))F_Q(\widehat{\Delta}^{\tau_{k_n}} v(h^{\tau_{k_n}}, c_{k_n});(\theta^Q, p^Q))\end{aligned}$$

with $\hat{v}^\tau(h^\tau)$ as described in Equation 6.2.

7 Estimation Results

This section discusses the results from the estimation of the parameters in the model.

7.1 Parameter Estimates

Table 4 presents the estimation results for the model parameters. Figure 3 illustrates the CDF of firms' arrival timing. Our estimates suggest that firms are more likely to arrive during the latter half of the entry period, with 70% of the firms arriving in this time frame. The median arrival time is 0.71, which corresponds to approximately a

Table 4: Estimated parameters of the model

Distribution	c_E: Truncated Normal on $[0,\infty)$	
	c_Q: Truncated Normal on $[0,\infty)$	
	τ: Beta	
	Estimate	S.E.
Entry		
Prob. of considering entry: p^E		
Const.	0.851	0.021
ln(# Pot bidder)	-0.231	0.009
μ_E	-2.926	0.015
σ_E	0.383	0.033
Disclosure		
Prob. of always disclosing: p^Q	0.268	0.019
μ_Q	-2.416	0.251
σ_Q	0.642	1.213
Timing		
α_τ	1.227	0.099
β_τ	0.661	0.052

Note: Table presents estimates of the model parameters. Standard errors are calculated using 100 bootstrap draws, with sampling at the auction level.

week before the forum closes.

Figure 4 shows the relationship between values of entry and entry probability in a scenario with 12 potential bidders, which is the median size of the bidders' pool. Firms consider entering with 28% probability when there are 12 potential bidders. This probability decreases with the number of potential bidders. Additionally, median size of entry costs is estimated as 3.4% of the engineer's estimate. Our estimate of entry costs is comparable with the numbers reported in the literature (Bajari et al. 2010, Krasnokutskaya & Seim 2011).

Figure 5 shows the relationship between values of disclosure and disclosure probability. Firms get in need for posting a question resulting in a baseline disclosure probability of 27%, which reflects the likelihood of disclosure even when it may be disadvantageous to them. As value of disclosure increases, disclosure probability also rises. For instance, when the value of disclosure is 1% of the estimated cost, firms disclose with a probability of 31%.

Table 5: Distribution of Construction Costs: by Construction Types

Construction Types	25-th percentile	Median	75-th percentile
Bridge	0.38	0.75	1.02
Overlay	0.74	0.88	1.01
Reconstruction	0.72	0.89	1.11
Safety	0.50	0.74	0.99
Others	0.56	0.74	0.97

Note: Total number of projects is 434. There were 5 auctions without an entrant. The presented numbers are fractions of the engineer's estimate.

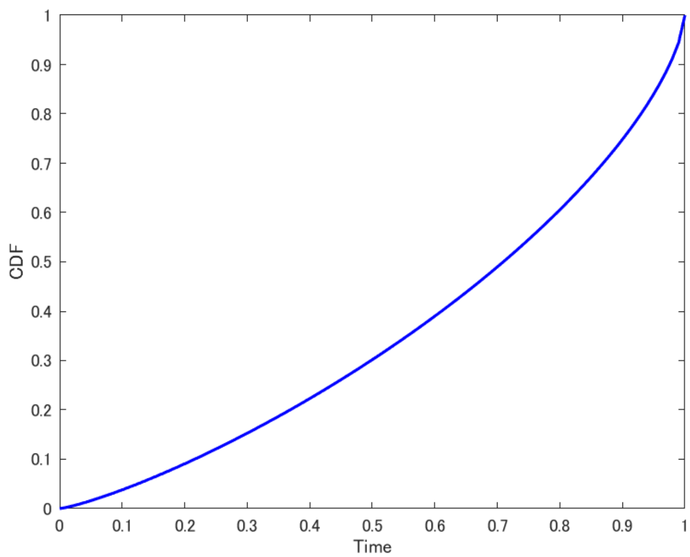

Figure 3: CDF of arrival timing

We summarize the estimated distributions of construction costs in Table 5. The table reports the median, 25th and 75th percentiles as fractions of the engineer's estimate for each construction type. The median construction cost is estimated to range from 74% to 89% of the engineer's estimate. Overall, projects related to overlay and reconstruction have higher construction costs compared to the other project types.

Table 6 presents estimation results regarding the distribution of opponents' best bids.[23] In a first-price auction, it is the opponents' best bid that ultimately determines an individual firm's profit. First, opponents' best bid becomes more aggressive as a

[23]Estimates for the distribution of the secret reserve price is presented in Appendix Table E.1.

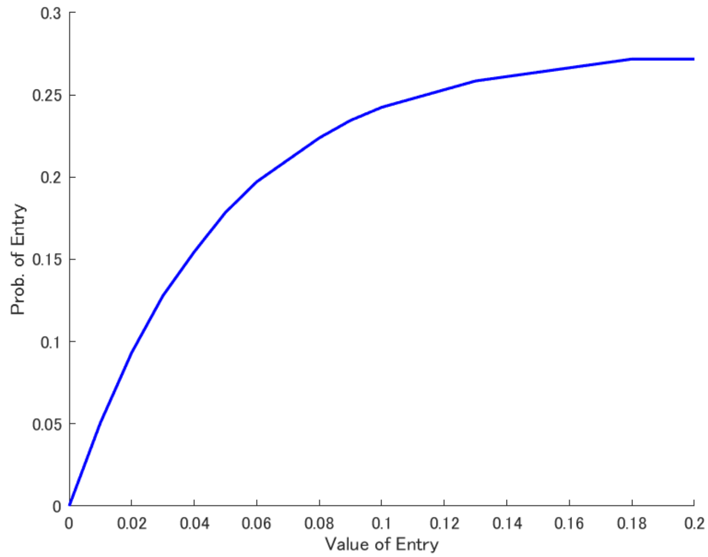

Figure 4: Value of entry and entry probability

Notes: This figure shows the relationship between values of entry and entry probability for the case where we have 12 potential bidders, which is the median size of entrants' pool.

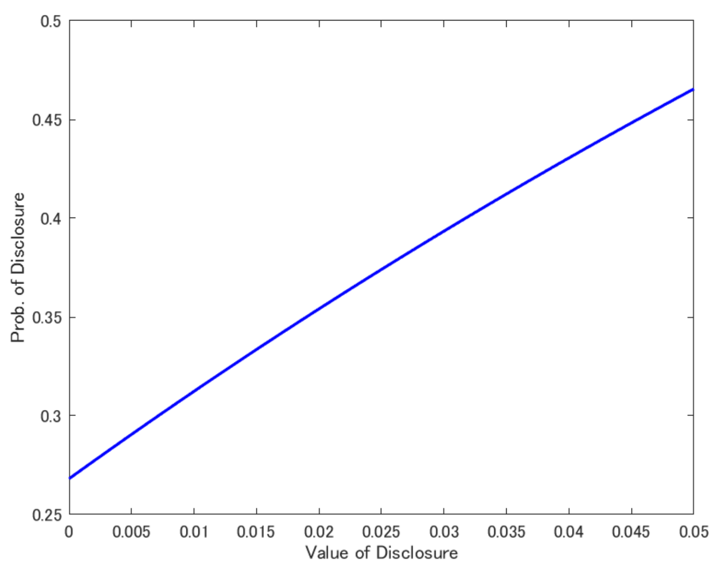

Figure 5: Value of disclosure and disclosure probability

Notes: This figure shows the relationship between value of disclosure and disclosure probability.

Table 6: Distribution of opponents' best bid: Log-normal

Variables	Estimate	S.E.
μ		
Constant	-0.023	0.067
Asked	0.044	0.027
Asked $\times \tau$	-0.045	0.033
ln(# Pot. Bidders)	-0.017	0.034
# Q from others	-0.037	0.010
Type:		
Overlay	0.066	0.030
Safety	0.018	0.050
Bridge	0.207	0.054
Recons	0.102	0.044
Others	Reference	
District:		
Missoula	Reference	
Butte	-0.027	0.028
Great Falls	0.050	0.029
Glendive	0.035	0.032
Billings	-0.022	0.043
$\log \sigma$		
Constant	-1.232	0.144
ln(# Pot. Bidders)	-0.018	0.082
# Q from others	-0.207	0.039
Type:		
Overlay	-0.596	0.100
Safety	0.043	0.134
Bridge	0.274	0.140
Recons	-0.240	0.139
Others	Reference	
District:		
Missoula	Reference	
Butte	-0.148	0.092
Great Falls	-0.149	0.091
Glendive	-0.028	0.094
Billings	0.320	0.123

Note: This table presents estimated parameters of the distribution of opponents' best bid. The opponents' best bid is defined as the minimum of the opponents' bid and the secret reserve price.

firm faces more disclosures (questions). This trend reflects the fact that disclosures are made by the *actual* entrants.

Next, the results suggest that making disclosures at earlier periods makes opponents' best bid less aggressive, if we hold others' disclosure behavior fixed. To illustrate this impact, we compare two scenarios: (i) Firm X discloses at $t = 0$ while no other firm discloses; and (ii) No firm discloses at all. If firm X places the median bid ($b_i = 1.03$), its probability of winning probability increase by 11.4 p.p. in scenario (i) compared to scenario (ii), for an auction on an overlay project in the Missoula district. Conversely, the estimates imply that a last minute disclosure would make opponents' best bid more aggressive, although this effect is not statistically significant.

These results align with our earlier discussion on the trade-off associated with entry disclosures. As noted, while disclosures can reduce the number of entrants, they may simultaneously provoke more aggressive bids from remaining entrants. Our results suggest that the former effect dominates for disclosures made during earlier periods, while the latter effect dominates when disclosures are made at the last minute, at a time close to $t = 1$.

It is important to note that these results do not account for the potential influence of one firm's disclosures on the disclosure behaviors of others.We now shift our focus to the value of disclosures, incorporating the evolution of disclosure history and allowing firms to optimize their bidding strategies. In what follows, the numbers and figures we present in this section will based on the auctions on overlay projects from the Missoula district, which has the mode for the number of auctions across (type of construction, district)-pairs and has the median number of potential bidders totaling 12.

Figure 6 shows how the value of disclosure changes over time and across different levels of firms' construction costs. The values shown in the figure are for the case where there is no disclosure up to the corresponding time. The results indicate that the value of disclosure decreases as time progresses. For example, a bidder with median construction cost ($c = 0.86$) would find the value of disclosure to be 1.5% of the engineer's estimate at $t = 0$. However, this value declines to 0.8% by $t = 0.5$, and ultimately becomes a loss of 0.04% at $t = 1$. This decreasing trend is consistent across various construction cost levels.

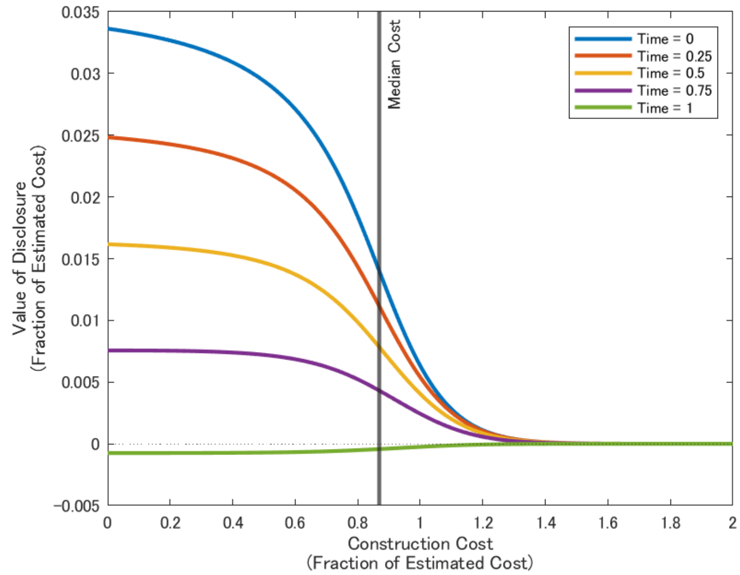

Figure 6: Value of disclosure and disclosure probability

Notes: This figure shows the relationship between values of disclosure and disclosure probability. The results are based on auctions on overlay projects from the Missoula district. The values are for the case where there is no disclosure up to the corresponding time.

At a given point in time, the value of disclosure tends to be lower for firms with higher construction costs, except when the timing approaches the end of the period at $t = 1$. For example, at $t = 0$, firms with construction costs at the 25th percentile ($c = 0.75$) would see a value of 2.1% of the engineer's estimate, while those at the median cost ($c = 0.86$) would see 1.5%, and firms at the 75-percentile cost ($c = 0.98$) would see 0.7%. This pattern suggests that the stronger entrants– those with low construction costs– are more likely to disclose entry. As a result, the disclosures reveal not only information about firms' entry but also signal the strength of those bidders. The entrants who have disclosed are likely to be strong bidders with low construction costs.

Finally, the value of disclosure at $t = 1$ turns out to be negative. When disclosures are made at the very end of the entry period, they fail to deter entry by others and instead prompt remaining entrants to bid more aggressively. Thus, firms disclosing at the last minute would incur a loss.

Next, we examine the value of entry for the firms over time, considering the number of disclosures available on the forum. Figure 7 illustrates the value of entry by time and number of disclosures. The values shown in the figure are for the case where the most

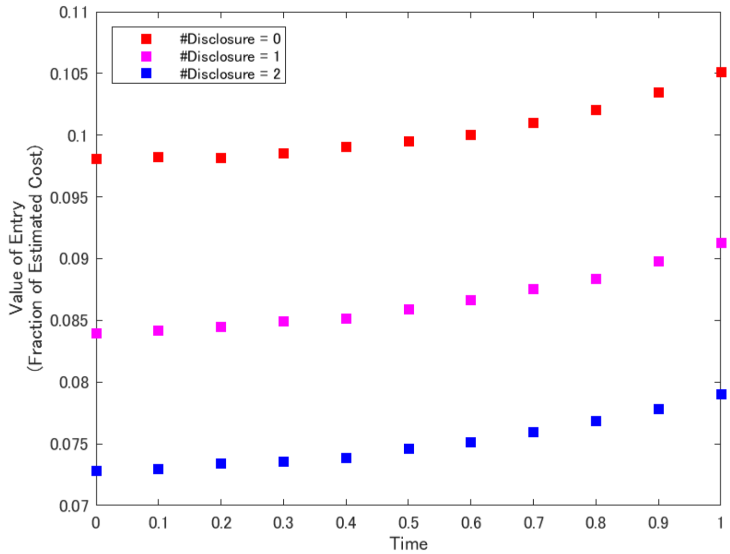

Figure 7: Value of entry

Notes: This figure shows the relationship between values of entry and entry timing, across different numbers of disclosures. The results are based on auctions on overlay projects from the Missoula district. The values are for the case where the most recent disclosure is made at $t = 0$ if there is one.

recent disclosure is made at $t = 0$ if there is one. As time progresses, the value of entry increases, provided that the number of disclosures remains constant. For example, with no disclosures, the value of entry starts at 9.8% of the engineer's estimate at $t = 0$, and rises to 10.5% by $t = 1$. As we would expect, this increase reflects that the absence of disclosures becomes more informative and valuable to firms arriving later in the period.

At any given point in time, having more disclosures reduces firms' value of entry. For example, having one more disclosure decreases a firm's entry value by 1.3–1.4 % of the engineer's estimate, compared to the case without disclosures. This corresponds to a 4–5% drop in entry probability. A second disclosure further lowers entry value by 1.1–1.2% of the engineer's estimate. Again, this corresponds to a 5–6% reduction in entry probability.

Finally, we analyze the value of arrival timing from an *ex-ante* perspective. Figure 8 presents values of entry based on arrival timing, regardless of whether firms decide to enter. Arriving at $t = 0$ yields an *ex-ante* value of 1.55% of the engineer's estimate, while arriving at $t = 1$ has a 7% lower value, 1.44% of the engineer's estimate.

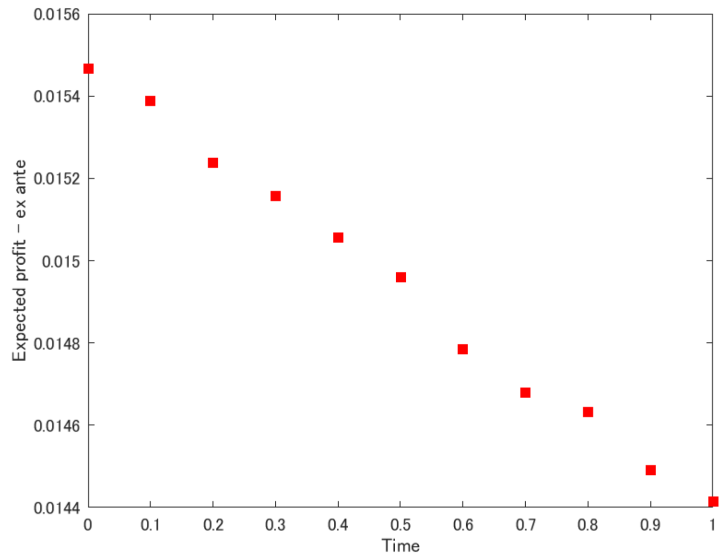

Figure 8: *Ex-ante* value of arrival timing

Notes: This figure shows the values of arrival time, from an *ex-ante* perspective. The results are based on auctions on overlay projects from the Missoula district.

Two opposing effects influence the value of arrival timing. Early arrival allows a firm to enter the auction and potentially deter others from entering by making a disclosure. However, early arrivals also encounter higher uncertainty about the number of entrants. In contrast, firms arriving later benefit from available disclosures, which can inform them about whether entry is advantageous, potentially avoiding inefficient auctions. In our setup, the benefit of early arrival is more substantial, suggesting that the potential for entry deterrence through disclosure outweighs the informational advantages of arriving later.

8 Counterfactual Analysis

In this section, we use our model and estimates to evaluate the performance of the current platform design, the Q&A forum, in comparison to alternative platform designs. We simulate how auction outcomes–the auctioneer's payment (conditional on the project getting allocated), the winner's construction cost, and entry behavior– would change under different designs for handling questions, or more broadly how entry information is treated. To understand the role of entry disclosure, we run three counterfactuals, summarized in Table 7.

Table 7: Description of the Counterfactuals

Counterfactual	Description	Entry Deterrence	Additional Info at Bid
(0) Shutdown	Q&A never becomes public		
(1) Last minute disclosure	Q&A revealed publicly at $t = 1$		✓
(2) Status quo	Current Q&A forum	✓	✓

It is important to emphasize that entry disclosure impacts the auction outcomes through two main channels: (i) entry deterrence – entry disclosure reduces the value of entry for firms arriving after the disclosure, potentially deterring their entry; and (ii) additional information at the bidding stage – a firm's disclosure may lead other entrants to bid more aggressively.

The first counterfactual, **(0) Shutdown**, corresponds to the case where we shut down the Q&A forum. In this case, the firms would communicate privately with the auctioneer if they have any questions about the project, and those questions would not be publicly visible. Consequently, entry disclosure would not be an option, removing both the potential for entry deterrence and the added information at the bidding stage.

The second counterfactual, **(1) Last minute disclosure**, considers a case where the Q&A forum becomes public only after $t = T(= 1)$ but before the bidding window closes. Here, firms can still submit questions but their entry would only be disclosed after the entry period ends. As a result, entry disclosures would not deter other firms from entering the auction, though they would still provide additional information about each firm's entry status at the bidding stage.

Our final counterfactual, (2) Status quo, represents the current setup with the current Q&A forum as implemented by MDOT. Disclosures are made public immediately upon posting, potentially deterring entry from other firms. Furthermore, these disclosures provide information to entrants during the bidding stage. According to our empirical estimates, firms with lower construction costs—typically stronger bidders—are more likely to disclose, meaning that disclosures signal both entry and entrant strength.

In the following sections, we simulate outcomes for auctions on overlay projects, which constitute the most common type of auction held by MDOT, to analyze how these alternative platform designs impact key metrics such as auctioneer payments, winner's construction costs, and entry behavior. We will use scenario (0) as our benchmark.

8.1 Last Minute Disclosure

First, we discuss the auction outcomes under counterfactual (1), where the Q&A forum becomes public after $t = 1$. In the equilibrium we have estimated, firms do not engage in costly disclosures, which are made for strategic purposes. Any disclosure made are from firms requiring information for exogenous reasons. This results in a disclosure rate of 27% among the entrants.

Figure 9 provides estimated changes in auction outcomes compared to our benchmark case, (0) Shutdown. Moving from a no-disclosure environment (0) to counterfactual (1), auctioneer's payment increases by 0.8%, which translates to an increase by $10,000 for a median-sized project. Moreover, we observe a loss in efficiency in terms of the winner's construction cost, increasing by 1.4%. In terms of entry, we see a increase in the number of entrants by 0.6% and 3.2% increase in the total entry cost.

Through disclosures, firms are giving up their information about their own entry, which is originally private information for them. In this counterfactual, some entrants are forced to give up such information since they are in need for asking a question through the forum. However, McAfee & McMillan (1987) and Harstad et al. (1990) have shown that whether or not bidders know the set of bidders essentially has no impact on the expected payment for the auctioneer. Therefore, overall level of information about entry does not directly change the auction outcomes.

Another factor that plays an important role here is asymmetry among the bidders. Note that in our benchmark case (0), entrants are in a symmetric position since there is no additional information for them. As long as the firms employ monotone and symmetric strategies in such scenario, the winner is the firm with the lowest construction cost, maintaining efficiency in allocation. This observation does not hold in our counterfactual case (1). Although firms are *ex-ante* symmetric, the entrants find themselves in asymmetric positions based on whether they have disclosed their entry or not. For example, let us consider a case where there are two entrants X and Y: firm X have disclosed entry, while Y have not, thereby an asymmetry in knowledge arises. Firm Y

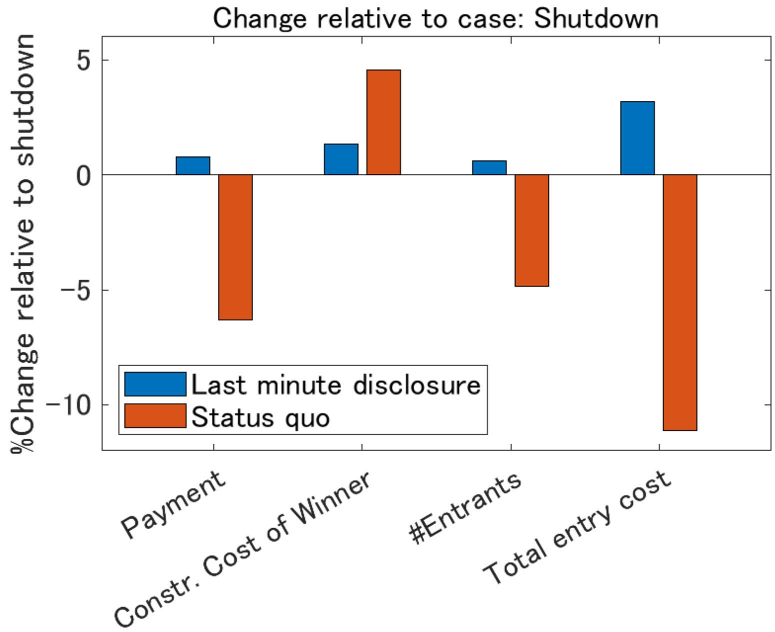

Figure 9: Changes in auction outcomes under different counterfactuals

Notes: Figure shows auction outcomes under different counterfactuals. The first two bars show the change in auctioneer's payment from scenario (0) to counterfactuals (1) and (2), respectively. The next two bars show changes in winner's construction cost. The rest of the bars show changes in the number of entrants and total entry costs.

knows that firm X is participating, but firm X remains uncertain about Firm Y's entry status. This difference in information leads Y to adopt a more aggressive bidding strategy than X, ultimately introducing inefficiencies. Consequently, there are cases where Y may win the auction despite having a higher construction cost than X, resulting in inefficiency in terms of winner selection. Furthermore, auctioneer's payment increases due to this asymmetry in beliefs about entrants. While the effect of asymmetry on auctioneer can go either way (Maskin & Riley 2000), auctioneer's payment increases in our case.

We observe a increase in number of entrants and total entry cost. As the rise in auctioneer's payment outweighs the increase in the winner's construction cost, value of entry increases in equilibrium. And as a result, number of entrants increases. While this increase in the number of entrants would counteract against the increase in payments, this force is not large enough to flip the sign. Finally, note that total entry cost increases by a larger fraction than the number of entrants because the firms who are marginal here are the firms who have the largest entry costs among the entrants.

8.2 Status quo

Next, we describe the auction outcomes under counterfactual (2), where we are in the status quo with the current Q&A forum. As we have seen in Section 7, the value of disclosure is more pronounced in the earlier stages of the entry period. Approximately one-third of the firms entering during the first half of the entry period choose to disclose entry, with about one-fifth of these disclosures made strategically, involving a payment of positive disclosure costs. Moreover, we have shown that firms opting to disclose tend to have lower construction costs. We find that, overall, the firms who disclose have 1.5% lower construction cost than the firms who do not disclose. Therefore, disclosures also act as a signal for strength of the firms.

The estimated changes in auction outcomes for counterfactual (2), the status quo, relative to our benchmark case, (0) Shutdown, are presented in Figure 9. By introducing the Q&A forum, corresponding to moving from our benchmark (0) to counterfactual (2), auctioneer's payment decreases by 6.3%, which is a substantial reduction. This corresponds to a decrease of $82,000 for a median-sized project. As in counterfactual (1), we see a loss in efficiency regarding the winner's construction cost compared to our benchmark scenario (0). Winner's construction cost increases by 4.5%, corresponding to a $38,000 increase for a median-sized project. This change is more significant than the change in counterfactual (1). In addition, we see a decrease in the number of entrants by 4.9% (equivalent to 0.15 entrants) and 11.1% decrease in total entry costs.

In this counterfactual disclosure conveys information in two dimensions: entry status and firms' strength. Stronger firms are more likely to disclose their entry status, which means that, in their efforts to deter entry from competitors, they relinquish not only their information rents related to their private entry status but also those pertaining to their construction costs. Unlike the scenario where information pertains solely to entry, this additional information about construction costs reduces the auctioneer's payment.

Another factor contributing to the decrease in the auctioneer's payment is the coordination of entry among bidders. A situation that the auctioneer would want to avoid is where bidders assign high probabilities to being the only entrant. With the availability of the forum, firms can gain information about others' entry intentions, resulting in a smaller fraction of auctions featuring only one bidder compared to our benchmark case. We observe that this fraction decreases by 3% due to the presence of the forum, in contrast to scenarios where entry decisions are made independently.

Entrants would be placed into an asymmetric position in this counterfactual as well. Let us consider the same example, there are two entrants X and Y: firm X has disclosed entry, while Y has not. From X's perspective, uncertainty remains regarding Y's entry status. Moreover, X recognizes that Y is likely a relatively weaker firm, as stronger firms are more prone to disclose their entry. On the other hand, Y is certain of X's entry and holds a belief that X is a relatively stronger firm. As a result, X is inclined to submit a weaker bid than it would in a situation without any information, while Y is tempted to submit a stronger bid. Therefore, this environment creates a larger gap in these firms' bidding strategies, which gives the firm with larger construction cost a greater chance of winning the auction. Consequently, we observe a larger efficiency loss in the winner's construction cost copared to counterfactual (1).

In terms of entry, we observe a significant decrease in number of entrants and total entry cost. With a decline in the auctioneer's payment and an increase in the winner's construction cost, the overall value of entry diminishes in equilibrium. The upward pressure on payments resulting from the decrease in the number of entrants is insufficient to reverse this trend.

In summary, the availability of this entry disclosure device–the Q&A forum–compels firms to engage in deterring others' entry through their disclosures. A key aspect of this setup is that firms differ along a new type dimension: arrival time. When assigned a strong type in this new dimension—meaning they arrive early—firms can effectively deter entry from competitors through their disclosures. Consequently, we observe a loss in efficiency regarding the winner's construction cost, as factors beyond construction costs now influence firms' strategies at the bidding stage. Additionally, as firms relinquish their information rents through disclosures to capitalize on their advantageous arrival time, auctioneer's payment decreases. Bernheim (1984) noted that the possibility of strategic entry deterrence has ambiguous effects on market concentration in scenarios where firms sequentially arrive at the market. In our setup, the entry disclosure device reduces the firms' expected profit from entry on average, leading to fewer entrants overall.

9 Conclusion

In this paper, we study how the option to disclose entry affects market outcomes by analyzing procurement auctions conducted by MDOT. We develop and estimate a model of a procurement auction with costly entry, where firms sequentially arrive at the market and make decisions on entry and disclosure. We present evidence that entry disclosure has two competing effects: it enables a firm to deter entry from others; and remaining entrants bid more aggressively in response to disclosures. Our analysis reveals that firms who disclose in early periods benefit from disclosures, as the deterrent effect of disclosure dominates the impact of more aggressive bidding from others. On the other hand, late disclosures are detrimental for the firms, as aggressive bidding by opponents becomes more pronounced. We also document that early arrivals are relatively more valuable in our setting since the firms can enjoy the gains from disclosures, even though firms have informational advantage when they arrive late.

We then use our model to compare alternative platform designs. Compared to a scenario where the Q&A forum is shut down– thus eliminating entry disclosure–the auctioneer's payment is lower under the current Q&A forum. Entry behavior becomes more efficient, as fewer firms choose to enter overall. However, this comes at the cost of efficiency in terms of the winner's construction cost. Thus, the auctioneer must carefully weigh this trade-off when deciding whether to implement such a platform. Two key factors drive these outcomes. First, the forum encourages early-arriving firms to disclose their entry status, which also signals their strength. As a result, firms forgo some information rents, leading to a reduction in the auctioneer's payment. Next, the forum allows the firms to coordinate their entry behavior, leading to a smaller fraction of auctions with few entrants. This coordination further contributes to the reduction in the auctioneer's payment.

Our analysis shows how transmission of information can alter market outcomes. We demonstrate that even a simple Q&A forum can serve as a tool for agents to transmit information strategically. Designing such a platform requires careful consideration, as it can significantly impact the market designer's objectives, such as welfare.

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Appendix

A Step 2 of Identification: Asymmetric Case

Suppose that under h^τ, bidders $j_1,\dots,j_J$ signals before i each at $\tau_{j_1},\dots,\tau_{j_J}$ ($\tau_{j_1}<\cdots<\tau_{j_J}$), and for the rest of bidders $k_1,\dots,k_K$, their signals are yet to be observed. Take τ_k such that $\tau_{j_m}<\tau_k<\tau$ holds for all m. Let

$$A_i^t(h,c_i)\equiv F_E^i(V_i^t(h))F_Q(\Delta v_i(h,c_i)) \tag{A.1}$$

We consider the following density P:

$$\begin{aligned}
P&=\Pr\Big(j_m \text{ signals at } \tau_{j_m}\,\forall m, i \text{ signals at } \tau, k_n \text{ does not signal before } \tau\,\forall n,\ \vec{c}_j, c_i\Big)\\
&=\prod_m f_\tau^{j_m}(\tau_{j_m})A_{j_m}^{\tau_{j_m}}(h^{\tau_{j_m}}(\tau_{j_1},\dots,\tau_{j_J}),c_{j_m})f_{c_{j_m}}(c_{j_m})\\
&\times\prod_n\left\{1-F_\tau^{k_n}(\tau)+\int_0^\infty\int_0^\tau f_\tau^{k_n}(t)\Big(1-A_{k_n}^t(h_t(\tau_{j_1},\dots,\tau_{j_J}),c_{k_n})\Big)f_{c_{k_n}}(c_{k_n})\,dt\,dc_{k_n}\right\}\\
&\times f_\tau^i(\tau)A_i^\tau(h^\tau(\tau_{j_1},\dots,\tau_{j_J}),c_i)f_{c_i}(c_i)
\end{aligned} \tag{A.2}$$

We consider the following density Q:

$$\begin{aligned}
Q&=\Pr\Big(j_m \text{ signals at } \tau_{j_m}\,\forall m, i \text{ does not signal before } \tau, k_n \text{ does not signal before } \tau\,\forall n,\ \vec{c}_j, c_i\Big)\\
&=\prod_m f_\tau^{j_m}(\tau_{j_m})A_{j_m}^{\tau_{j_m}}(h^{\tau_{j_m}}(\tau_{j_1},\dots,\tau_{j_J}),c_{j_m})f_{c_{j_m}}(c_{j_m})\\
&\times\prod_n\left\{1-F_\tau^{k_n}(\tau)+\int_0^\infty\int_0^\tau f_\tau^{k_n}(t)\Big(1-A_{k_n}^t(h_t(\tau_{j_1},\dots,\tau_{j_J}),c_{k_n})\Big)f_{c_{k_n}}(c_{k_n})\,dt\,dc_{k_n}\right\}\\
&\times\left\{1-F_\tau^i(\tau)+\int_0^\infty\int_0^\tau f_\tau^i(t)\Big(1-A_i^t(h_t(\tau_{j_1},\dots,\tau_{j_J}),c_i)\Big)f_{c_i}(c_i)\,dt\,dc_i\right\}
\end{aligned} \tag{A.3}$$

Taking the ratio between these two densities gives us:

$$P/Q = \frac{f_\tau^i(\tau)A_i^\tau(h^\tau(\tau_{j_1},\dots,\tau_{j_J}),c_i)f_{c_i}(c_i)}{\left\{1-F_\tau^i(\tau)+\int_0^\infty\int_0^\tau f_\tau^i(t)\left(1-A_i^t(h_t(\tau_{j_1},\dots,\tau_{j_J}),c_i)\right)f_{c_i}(c_i)dt\,dc_i\right\}} \tag{A.4}$$

Exploiting the relation that

$$\frac{\partial(1-F_\tau^i(\tau)+\int_0^\infty\int_0^\tau f_\tau^i(t)\left(1-A_i^t(h^\tau,c_i)\right)f_c(c_i)dt\,dc_i)}{\partial\tau} = \int_0^\infty f_\tau^i(\tau)A_i^\tau(h^\tau(\tau_{j_1},\dots,\tau_{j_J}),c_i)f_c(c_i)dc_i,$$

the function

$$\begin{aligned}\Gamma_i(\tau;h^\tau=(\tau_{j_1},\dots,\tau_{j_J})) &= 1-F_\tau^i(\tau)+\int_0^\infty\int_0^\tau f_\tau^i(t)\left(1-A_i^t(h^\tau,c_i)\right)f_c(c_i)dt\,dc_i\\ &= 1-\int_0^\infty\int_0^\tau f_\tau^i(t)A_i^t(h^\tau,c_i)f_c(c_i)dt\,dc_i\end{aligned}$$

is identified up to scale for all $\tau\in[\tau_{j_J},T]$. Since $\Gamma_i(0;h^\tau=\phi)$=1 holds, $\Gamma_i(\tau;h^\tau=\phi)$ is identified. Therefore, $f_\tau^i(\tau)A_i^\tau(h^\tau=\phi,c_i)f_c(c_i)$ is identified for all $\tau\in[0,T]$.

Now, given that $f_\tau^i(\tau)A_i^\tau(h^\tau=\phi,c_i)f_c(c_i)$ is identified, $\Gamma_i(\tau;h^\tau=\tau)$ is identified. As a result, $\Gamma_i(t;h^t=\tau)$ $(t\geq\tau)$ such that h^t includes one disclosure at τ is identified. By induction on the number of disclosures made, repeating this argument will allow us to identify $\Gamma_i(t;h^\tau)$ for all histories h^τ. Note that $f_\tau^i(\tau)A_i^\tau(h^\tau,c_i)f_c(c_i)$ is also identified for all h^τ.

Let

$$\begin{aligned}R = &\prod_m f_\tau^{j_m}(\tau_{j_m})A_{j_m}^{\tau_{j_m}}(h^{\tau_{j_m}}(\tau_{j_1},\dots,\tau_{j_{m-1}}),c_{j_m})f_{c_{j_m}}(c_{j_m})\\ &\times\prod_p f_\tau^{l_p}(\tau_{l_p})A_{l_p}^{\tau_{l_p}}(h^{\tau_{l_p}}(\tau_{j_1},\dots,\tau_{j_J},\tau_{l_1},\dots,\tau_{l_{p-1}}),c_{l_p})f_{c_{l_p}}(c_{l_p})\\ &\times\prod_n\Gamma_{k_n}(T;h^\tau=(\tau_{j_1},\dots,\tau_{j_J},\tau_{l_1},\dots,\tau_{l_L}))\end{aligned}$$

and

$$
\begin{aligned}
S = & \prod_m f_\tau^{j_m}(\tau_{j_m}) A_{j_m}^{\tau_{j_m}}(h^{\tau_{j_m}}(\tau_{j_1}, \ldots, \tau_{j_{m-1}}), c_{j_m}) f_{c_{j_m}}(c_{j_m}) \\
& \times \prod_p \Gamma_{l_p}(\tau; h^\tau = (\tau_{j_1}, \ldots, \tau_{j_J})) \\
& \times \prod_n \Gamma_{k_n}(\tau; h^\tau = (\tau_{j_1}, \ldots, \tau_{j_J})).
\end{aligned}
$$

Since all the objects that appear in R and S are identified, R and S are identified.

Belief of i can be written as:

$$
\Pr_i(h^T | h^\tau, \tau_i = \tau, A_i^Q = 0) = R/S
$$

and since R and S are identified, this object is also identified.

B Proof: Equilibrium for Two-agent Example

Let agent i's inverse bid function be $\phi_i = \beta_i^{-1}$. Cost is distributed $\sim U[0,1]$. Player 1 enters with probability 1. Player 1's belief on Player 2's entry is with probability r. Let the reserve price be $R = 1$.

Derivation and proof for β_1 and β_2 being the equilibrium bidding strategies when Player 1 enters and discloses while Player 2 enters but does not disclose, follows Kaplan & Zamir (2012).

Here, we focus on the proof of optimality of the disclosure strategies taken in our example. First, let us consider the required condition that forces the first entrant to disclose. To consider this condition, let us first prove the following claim:

Claim: Fix r. $\phi_1(b) > r\phi_2(b)$ for all $b \in \left(\frac{1}{1+r}, 1\right)$. Note that support of the bids for each player is $\left[\frac{1}{1+r}, 1\right]$.

Proof: Let $X = \frac{r^2}{(1-r)^2}\log\frac{1-b}{\frac{1}{r}-b} - r(1+r) - \frac{2r^2}{(1-r)^2}\log(r) - \frac{r^2(1+r)}{1-r}$. Then

$$\phi_1 = 1 - \frac{1}{(b-\frac{1}{r})X - \frac{r}{1-r}},\ \phi_2 = \frac{1}{r} - \frac{1}{-(b-1)X + \frac{r}{1-r}}$$

To show $\phi_1 > r\phi_2$, it is equivalent to show that:

$$-r(1+r)/(1-r) > (2 - br - b)X$$

holds. Let $h(b) = (2 - br - b)X$. Note that $h(\frac{1}{1+r}) = -r(1+r)/(1-r)$. Observe that:

$$h'(b) = -(1+r)X + (2 - br - b)\frac{r^2}{(1-r)^2}\left(\frac{1}{b-1} - \frac{1}{b-\frac{1}{r}}\right)$$

Again, note that $h'(\frac{1}{1+r}) = 0$. Next,

$$\begin{aligned} h''(b) &= -2(1+r)\frac{r^2}{(1-r)^2}\left(\frac{1}{b-1} - \frac{1}{b-\frac{1}{r}}\right) + (2 - br - b)\frac{r^2}{(1-r)^2}\left(-\frac{1}{(b-1)^2} + \frac{1}{(b-\frac{1}{r})^2}\right) \\ &= \frac{1}{(1-r)^2}(r-1)^3 b < 0 \end{aligned}$$

Thus, $h'(b) < 0$ for all $b \in (\frac{1}{1+r}, 1)$. Therefore, $h(b) < -r(1+r)/(1-r)$ holds for all $b \in (\frac{1}{1+r}, 1)$. This is what we wanted to show. ■

Now, we are ready to prove the following claim.

Claim: Fix r. $EU_1(c) > EU_2(c)$ for all $c \in (0,1)$. $EU_i(c)$ is the expected utility for Player i conditional on entering and cost c, when players take strategies β_i and β_j.

Proof: Observe that:

$$\begin{aligned} EU_1(c) &= (\beta_1(c) - c)(1-r) + (\beta_1(c) - c)r(1-\phi_2(\beta_1(c))) \\ &= (b_1(c) - c)(1 - r\phi_2(\beta_1(c))) \end{aligned}$$

and

$$EU_2(c) = (b_2(c) - c)(1 - \phi_1(b_2(c))).$$

By the previous claim, we know that $r\phi_2(b_2(c)) < \phi_1(b_2(c))$. Now, the following holds:

$$\begin{aligned} (b_1(c) - c)(1 - r\phi_2(b_1(c))) &\geq (b_2(c) - c)(1 - r\phi_2(b_2(c))) \\ &> (b_2(c) - c)(1 - \phi_1(b_2(c))) \end{aligned}$$

Hence, $EU_1(c) > EU_2(c)$ holds for all $c \in (0,1)$. ■

This claim implies that if a Player is entering, they prefer being in the position of Player 1. Therefore, if you arrive and enter first, it is optimal for the player to disclose their entry.

The next required condition is that if you are the second entrant facing one disclosure, you do not disclose. To show that this condition holds, we prove the following claim:

Claim: $2b - 1 > \phi_1(b)$ for all $b \in (\frac{1}{1+r}, 1)$ when $r < 1$.

Proof: We will prove $\frac{1}{2(1-b)} > \frac{1}{1-\phi_1}$. Let

$$H(b) = \frac{1}{2(1-b)} - (b - \frac{1}{r})X + \frac{r}{1-r},$$

where $X = \frac{r^2}{(1-r)^2} \log \frac{1-b}{\frac{1}{r}-b} - r(1+r) - \frac{2r^2}{(1-r)^2} \log(r) - \frac{r^2(1+r)}{1-r}$. We shall show $H(b) > 0$ for all $b \in (\frac{1}{1+r}, 1)$. Observe that:

$$H'(b) = \frac{1}{2(1-b)^2} - \left(b - \frac{1}{r}\right) \frac{r^2}{(1-r)^2} \left(\frac{1}{b-1} - \frac{1}{b-\frac{1}{r}}\right) - X$$

and

$$H'\left(\frac{1}{1+r}\right) = \frac{1}{2r^2}(1-r^2)(1+2r) > 0$$

Next,

$$\begin{aligned}
H''(b) &= \frac{1}{(1-b)^3} - \frac{2r^2}{(1-r)^2}\left(\frac{1}{b-1} - \frac{1}{b-\frac{1}{r}}\right) - \left(b - \frac{1}{r}\right)\frac{r^2}{(1-r)^2}\left(-\frac{1}{(b-1)^2} + \frac{1}{(b-\frac{1}{r})^2}\right) \\
&= \frac{1}{(b-1)^3(b-\frac{1}{r})} \frac{r^2}{(1-r)^2} \frac{1-r}{r}\left[-\frac{1-r}{r}(b-\frac{1}{r}) + 2(b-1)^2 + (b-1)(-2b+1+\frac{1}{r})\right] \\
&= \frac{1}{(b-1)^3(b-\frac{1}{r})} \frac{r}{(1-r)}\left[-\frac{1-r}{r}(b-\frac{1}{r}) + 2(b-1)^2 + (b-1)(-2b+1+\frac{1}{r})\right] \\
&= \frac{1}{(b-1)^3(b-\frac{1}{r})} \frac{r}{(1-r)}\left(\frac{1}{r} - 1\right)^2 > 0
\end{aligned}$$

Thus, $H'(b) > 0$ holds for all $b \in (\frac{1}{1+r}, 1)$. Moreover, since $H(\frac{1}{1+r}) > 0$, we get $H(b) > 0$ for all $b \in (\frac{1}{1+r}, 1)$. This completes our proof. ■

Now, to complete our discussion, we show that it is optimal for the second entrant to not disclose.

Claim: Let the expected player's profit be $V(c)$ when both bidders take strategy $b(c) = \frac{c+1}{2}$. Then, $EU_2(c) > V(c)$ holds.

Proof: Observe that:

$$\begin{aligned}
V(c) &= (b(c) - c)(1 - (2b(c) - 1)) \\
&< (b(c) - c)(1 - \phi_1(b(c))) \\
&\leq (\beta_2(c) - c)(1 - \phi_1(\beta_2(c))) \\
&= EU_2(c).
\end{aligned}$$

First inequality holds since $2b - 1 > \phi_1(b)$ holds by the previous claim. The second inequality holds by the optimality of β_2 when the other bidder employs β_1. ■

Combining the results from these claims, we have shown that the disclosure behavior presented in our example satisfies the equilibrium requirements.

C Details on the Estimation

We discuss the details on the estimation that we omit from the main text.

Step 1. Construction costs c_i We estimate G^{-i}, the CDF of the minimum of the bids among the opponents and the secret reserve price. We assume that G^{-i} and the secret reserve price both follows a log-normal distribution. Parametric specification of G^{-i} is given in the main text. We assume that secret reserve price follows log-$\mathcal{N}(\mu^r, \sigma^r)$.

We split our observations into four cases, and show the corresponding likelihood for each case below:

1. When winner was accepted but the bidder lost the auction:

$$g_{-i}(b)$$

   where b is the winner's bid.

2. When you are the winner but rejected:

$$\frac{\int_0^b g_{-i}(\tilde{b}) f_r(\tilde{b}) d\tilde{b}}{F_r(b)}$$

3. When you are the winner and accepted, there is another bidder:

$$\frac{g_{-i}(b^2)(1 - F_r(b^2)) + \int_b^{b^2} g_{-i}(\tilde{b}) f_r(\tilde{b}) d\tilde{b}}{1 - F_r(b)}$$

   where b is the winner's bid and b^2 is the highest opponent's bid.

4. When you are the winner and accepted, there is no other bidder:

$$\frac{\int_b^{+\infty} g_{-i}(\tilde{b}) f_r(\tilde{b}) d\tilde{b}}{1 - F_r(b)}$$

   where b is the winner's bid and b^2 is the highest opponent's bid.

Using this likelihood, we estimate parameters for G^{-i} and the distribution of secret reserve price via maximum likelihood. Integration is computed by evaluating values on a grid.

Given our estimate $\hat{G}^{-i}$, we estimate construction costs for each entrant by:

$$\hat{c}_i = b_i - \frac{1-\hat{G}_{-i}(b)}{\hat{g}_{-i}(b)}.$$

Step 2. Belief on the evolution of disclosure history Parameters regarding the distribution of time intervals between the n-th and $(n+1)$-th disclosure, $(\beta^{\mu_t}, \beta^{\sigma_t})$ are estimated via maximum likelihood as described in the main text.

Given the estimates on time intervals, we estimate the belief of a firm when the firm discloses at some time τ facing history h^{τ}. To obtain this estimate, we simulate the evolution of disclosure histories. The simulation procedure proceeds as follows:

1. Suppose that a firm makes the n-th disclosure. Fix the start timing $\tau^n \in \{0, 0.05, 0.1, \ldots, 0.95\}$.

2. Draw the timing of the next disclosure τ^{n+1}. If the next disclosure does not exist, terminate. Otherwise, repeat this step until the next disclosure does not exist or there are no potential bidders left.

We take 10,000 draws for each τ^n. This gives us the estimated belief $\hat{\mu}_i$ for cases where i discloses.

Next, we estimate the belief of a firm when the firm enters but does not disclose. To obtain this estimate, we again simulate the evolution of disclosure histories. The simulation procedure proceeds as follows:

1. Suppose that a firm observes n disclosures. Fix the entry timing $\tau \in \{0, 0.05, 0.1, \ldots, 0.95\}$. Also, fix the timing of the latest question $\tau^n \in \{0, \ldots, \tau\}$ ($\tau^0 = 0$ if $n = 0$).

2. Draw the timing of the next disclosure τ^{n+1}. To make a draw, we exploit the fol-

lowing relationship, which we have shown as equation 5.3:

$$
\begin{aligned}
&\Pr(\tau^{n+1} > t \text{ or } (n+1)\text{-th disclosure does not exist})^{(M-1)/M} \\
&= \mu_i(\tau^{n+1} > t \text{ or } (n+1)\text{-th disclosure does not exist})
\end{aligned}
$$

where M is the number of potential entrants who have not disclosed at τ, including firm i. If there are no disclosures beyond, terminate.

3. We draw the next disclosure timing until the draw suggests that next disclosure does not exist. Here , we exploit:

$$
\begin{aligned}
&\Pr(\tau^{n+k} > t \text{ or } (n+k)\text{-th discl. does not exist} \,|\, (n+k-1)\text{-th discl. is at } \tau^{n+k-1})^{(M-k)/(M-k+1)} \\
&= \mu_i(\tau^{n+k} > t \text{ or } (n+k)\text{-th discl. does not exist} \,|\, (n+k-1)\text{-th discl. is at } \tau^{n+k-1}).
\end{aligned}
$$

We take 10,000 draws for each tuple (τ, n, τ^n). This gives us the estimated belief $\hat{\mu}_i$ for cases where i does not disclose.

When we need to evaluate $\hat{\mu}_i$ when timings are not on the grid $\{0, 0.05, \ldots, 1\}$, we make a linear interpolation.

Step 3. Value of disclosure In this step, we aim to obtain an estimate for the value of disclosures. First, we estimate the value from bidding conditional on time-T history $V_i(h^T, c)$ by:

$$\hat{V}_i(h^T, c) = \max_b (b - c)(1 - \hat{G}_{-i}(b|h^T)),$$

where $\hat{G}_{-i}$ is the estimated CDF of the lowest bid from opponents. We estimate this object for all h^T and for all values of estimated construction costs. For h^T, we include the number of disclosures from opponents, a dummy for whether i disclosed, and i's disclosure timing. we evaluate $\hat{V}_i$ on a grid of disclosure timings: $\{0, 0.05, \ldots, 1\}$. A linear interpolation is made when necessary.

Next, we estimate the values with and without disclosure, $v^{1,\tau}(h^\tau, c)$ and $v^{0,\tau}(h^\tau, c)$.

This value is estimated by:

$$\hat{v}^{j,\tau}(h^\tau, c) = \int \hat{V}_i(h^T, c)\, \hat{\mu}_i(h^T | h^\tau, \tau_i = \tau, a_i^Q = j)\, dh^T$$

for $j = 0, 1$. Note that although we have expressed this as an integration, due to our estimation procedure, $\hat{\mu}_i$ is a discrete distribution. Therefore, this calculation turns out to be a summation, in practice. We estimate these objects for all h^τ and for all values of estimated construction costs. For h^τ, we include the number of disclosures from opponents and the most recent disclosure timing. The values are evaluated on a grid of time τ: $\{0, 0.05, \ldots, 1\}$. A linear interpolation is made when necessary.

Then, value of disclosure $\Delta v^\tau(h^\tau, c)$ can be estimated as:

$$\widehat{\Delta v}^\tau(h^\tau, c) = \hat{v}^{1,\tau}(h^\tau, c) - \hat{v}^{0,\tau}(h^\tau, c).$$

Step 4. Model primitives The model primitives are estimated via maximum likelihood as described in the main text. We calculate standard errors via bootstrapping. Our final procedure bootstraps over the entire estimation procedure to incorporate estimation error in earlier steps.

D Simulating the Status Quo and Model Fit

We simulate the auction outcome under status quo using our estimates to consider counterfactuals and evaluate the model fit. The procedure is as follows:

1. For each potential bidder i, we draw a tuple $(\tau_i, c_i^E, c_i^Q, c_i)$ – arrival timing, entry cost, disclosure cost, and construction cost–. Moreover, we make draws for whether i considers entry and whether i is forced to disclose.

2. Starting from the firm with the earliest arrival timing, we determine their actions on entry and disclosure. For entry, we use the estimated value of entry $\hat{v}^{\tau_i}(h^{\tau_i})$ to assign the entry action. For disclosures, we use the estimated value of disclosure $\widehat{\Delta v}^{\tau_i}(h^{\tau_i}, c_i)$.

3. Repeat the previous step until all the actions are determined for the firm with the latest arrival timing.

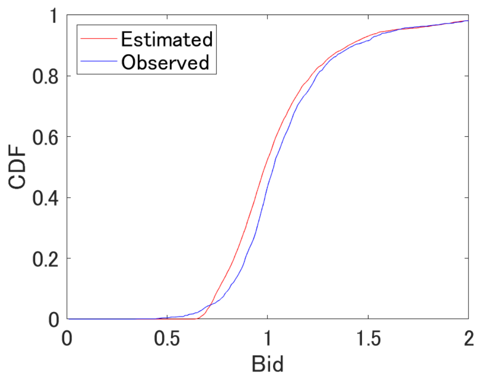
4. Now that the time-T history h^T is determined, we solve:

$$\arg\max_b (b - c_i)(1 - \hat{G}_{-i}(b|h^T))$$

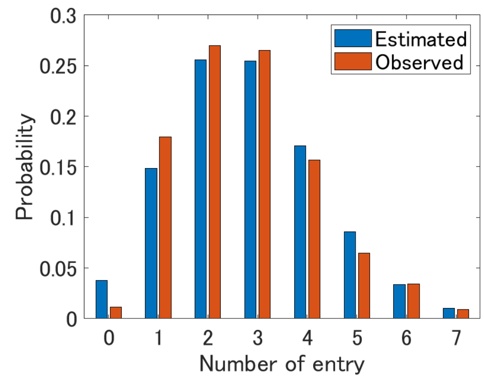
   and obtain b_i for each entrant.

We repeat this procedure for 10,000 times.

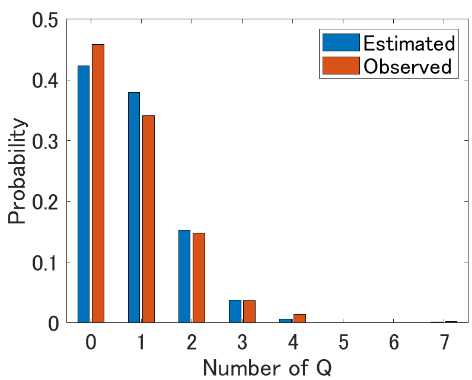
Figure 10 shows the observed and simulated outcomes from the auction. The model does relatively well fitting the overall shape of the actual bid distribution, number of entrants, number of disclosures, and timing of disclosures.



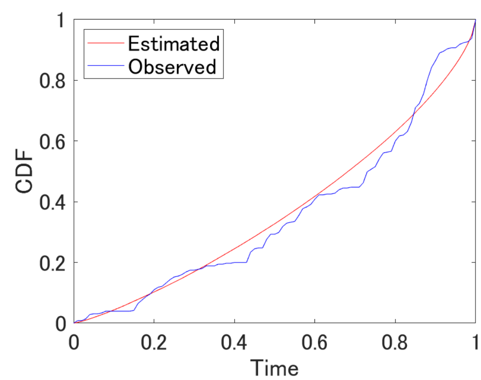
(a) Bid



(b) Number of entrants



(c) Number of disclosures



(d) Timing of disclosures

Figure 10: Model Fit

E Appendix Tables

Table E.1: Secret reserve price

Distribution: Log-normal		
Parameters	Estimate	S.E.
μ	0.738	0.079
σ	0.261	0.057

Note: Table shows parameters for the distribution of the secret reserve price.

Table E.2: History Transition

Variables	Estimate	S.E.
μ_t		
Constant	0.720	0.358
# Q posted (n)	-0.214	0.141
ln(# Pot. Bidders not posted Q yet +1)	0.099	0.136
Time of previous Q (τ^n)	-0.873	0.164
Type:		
Overlay	-0.222	0.081
Safety	-0.054	0.099
Bridge	-0.291	0.100
Recons	-0.655	0.135
Others	Reference	
District:		
Missoula	Reference	
Butte	0.060	0.071
Great Falls	0.133	0.068
Glendive	0.079	0.082
Billings	0.130	0.089
log σ_t		
Constant	0.447	0.248
# Q posted (n)	0.237	0.433
ln(# Pot. Bidders not posted Q yet +1)	-0.407	0.131

Note: This table presents estimated parameters $(\beta^{\mu_t}, \sigma^{\sigma_t})$ that relates to the distribution of $(n+1)$-th disclosure, conditional on the n-th disclosure. The specification is described in Step 2 from Section 6.2.